

# PART E - STANDARD CONSTRUCTION PROCEDURES

This Part of the Manual is organized using section numbering similar to what is used in the Standard Specifications. Thus, for example, if the Inspector is overseeing excavation, which is covered in Section 202 of the Specifications, then the Inspector should refer to Section E202 of this Manual for information and instructions on inspecting excavation work.

## DIVISION E200 – EARTHWORK

### SECTION E200 – GENERAL EARTHWORK INFORMATION

**E200.01 General.** Earthwork is the first work performed on most construction projects. It encompasses a number of activities, from clearing the site to excavating for structures or pipes. The earthwork done on a project prepares the site for other construction work, such as building bridges and paving roads. Problems with earthwork often do not become apparent until other construction work has been done, at which point the effort to correct the problems is both time consuming and expensive. Therefore, earthwork operations must be carefully inspected to ensure that the work done is in accordance with the Specifications. The Inspector should closely observe all earthwork operations and bring all problems to the attention of the Contractor and, when necessary, the Engineer.

This Division of the Manual addresses most aspects of earthwork that may be performed on a project. The information provided here is intended to explain construction procedures to the Inspector, define the Inspector's duties regarding earthwork inspection, and serve as a companion for use with the Specifications. The Inspector should read this section of the Manual before earthwork begins on a project to ensure the proper performance of the Inspector's duties.

**E200.02 Preparation of Right-of-Way to the Limits of Construction.** The initial operation to be undertaken in the construction of a highway facility is the preparation of the right-of-way and any designated easements. All obstructions and objectionable materials are to be removed and disposed of in accordance with the Specifications. Items to be removed include trees, undergrowth, stumps, rubbish, buildings, foundations, abandoned utilities and drainage structures, and any other materials or objects not needed in the construction or of an undesirable nature. [110.07] [201] [202.03] [202.04] [211.01] [211.02]

**E200.03 Protection and Preservation of Property.** The Contractor is responsible for the protection and preservation of all public and private property along and adjacent to the roadway. [107.09] The Plans and Specifications will provide detailed instructions for clearing the Project site, but in general, the following should be considered:

- (a) The boundaries of all areas in which the Contractor will be required to perform work should be clearly marked by survey stakes. These boundaries include right-of-way lines, limit-of-construction lines, and wetland boundaries. It should be made clear to the Contractor and adjacent property owners what ingress and egress has been provided for their access to the Project. [105.10]

- (b) This is the proper time for the Engineer and the Contractor, or their representatives, to travel over the Project site and discuss the general work to be done and any special details. These details will include trees to be saved, stakes and survey control points to be preserved, and all known utilities to be protected from damage during clearing operations. The general clearing procedures and the plan for disposal of materials should also be discussed.
- (c) A careful investigation should be made to determine the location of all underground facilities within the right-of-way. With adequate knowledge of their location and depth, underground facilities within the right-of-way can be protected against damage during the Contractor's clearing, grubbing, and excavation work. Prior to beginning any clearing and grubbing work, the Inspector should ensure that the Contractor knows the location and depth of all underground utilities within the right-of-way so that the locations can be established on the ground. The Contractor must contact "Miss Utility", the Statewide utility work information system. The Inspector should ensure this has been done and is up to date before utility work begins. There are occasions when utilities are in place at the time the Contract is awarded that are to be removed or relocated within the right-of-way after certain construction operations are complete. The Contractor must coordinate with the appropriate utilities regarding the intended time of their removal or relocation so that the Contractor can properly coordinate its construction operations with the activities of the utility company involved. **[105.09] [107.04]**
- (d) All trees, shrubs, survey or historical markers, objects of historical or archeological value, and other items that are to be preserved or remain in place must be clearly marked and the Contractor made aware of their location. **[201.03]**
- (e) The Contractor must protect all private or public property adjacent to the right-of-way, and all natural growth and improvements thereon, from damage by its equipment and any construction operations that are under way. When property is damaged by the Contractor's equipment or operations, it is the Contractor's sole responsibility to rebuild, repair, or make good such damage or injury at its expense. The manner in which a Contractor preserves and protects such property should be the Contractor's choice as long as it is reasonable and consistent with good construction practice. The Engineer will refrain from directing how this protection should be accomplished unless it is stated in the Plans and Specifications. **[107.09] [201.01] [201.03]**
- (f) Care should be taken that property lines are respected and that property owners are advised of clearing operations, the extent of work involved, and the effect it might have on the property owner.

**E200.04 Inspector's Checklist for General Earthwork.**

- (a) *Plans:* Study and become familiar with the Plans and Specifications as they affect the Project.
- (b) *Project Site:* Become familiar with the Project site. Understand the terrain, the obstacles, and the material present on site.
- (c) *Drainage:* From the Plans and the Inspector's familiarity with the Project site, understand the drainage flows of the area. Keep in mind present and future

conditions that may change as construction progresses. Ensure that proposed erosion and sediment control methods are going to be sufficient to protect adjacent property, ditches, streams, rivers, and wetlands.

- (d) *Material*: Be familiar with the material on site and the material in designated borrow sources. Verify that material used on the Project is coming from approved sources. Be able to recognize any significant change in material coming to the Project that may affect embankment placement and compaction. Be watchful for existing material excavated that can be used as select material within the Project limits.
- (e) *Materials and Research Laboratory*: Understand the operation of the Materials and Research Section. Coordinate all field testing required on the Project with the Materials and Research Section. Know and recognize lab test procedures that are conducted on or for the Project. If needed, the Materials and Research Section can help determine whether existing material needs to be undercut. **[106.05]**
- (f) *Plan of Work*: Maintain communication with the Contractor's personnel. Hold frequent conversations with the Contractor's supervisory personnel in order to understand the Contractor's plan for and sequence of construction operations. Acquire enough information to anticipate changes in the Contractor's plan of work.
- (g) *Grade Stakes*: Grade stakes are an important item in earthwork control. Ensure that the Contractor makes use of this engineering control method. Also, make sure that all required stakes are maintained throughout excavation and embankment placement operations. **[105.10]**
- (h) *Locke Level*: Become familiar with the use of the Locke Level. By using the Locke Level, the Inspector can spot-check grades and slope ratios and ensure that the Project is being built in accordance with the Plans. Understand both the value and the limitations of the tool.
- (i) *Equipment*: Become familiar with the equipment used by the Contractor. Know the methods of operation and the capacities of hauling and excavation equipment. Knowledge of construction equipment is a prerequisite for qualification as an Inspector of earthwork operations. This knowledge will help the Inspector control the Project through a more complete understanding of a particular operation.
- (j) *Weather*: The Inspector should always be familiar with the weather forecast. The Inspector should know how various weather conditions will affect the Project. The Inspector should look at the Project every day as if it were definitely going to rain the next day. When the next day comes with adverse weather, the Inspector will be prepared. The Inspector will know what to do and what to suggest to the Contractor to minimize the detrimental effect on the Project.

### ***Historical Perspective***

#### **Importance of Earthwork**

Earthwork, though broad by its many aspects, is a specific and important engineered phase of construction. Engineered earthwork begins with a soils investigation and ends as a foundation for all construction. The widest highway, the longest bridge, and the tallest building could not exist were it not for a solid foundation; this foundation is earthwork.

**History of Soils Engineering**

Early construction of roads in the United States usually involved only small amounts of earthwork. This was done by horse-drawn graders and scrapers and little or no thought was given to soils and types of compaction. Usually if any portion of the road was rolled, it was only the paved area. The advent of powered excavating and hauling equipment that followed the coming of the automobile resulted in marked increases in the depths of cuts, heights of fills, and total earthwork quantities in road construction. Early fills were constructed by end-dumping the loose soil without benefit of compaction as filling progressed. Fill "settlement" was usually considered largely a function of time. Paving was delayed until the fill had sufficient time to settle without knowledge of when settlement would be complete.

The growing numbers of automobiles during the 1920's brought increasing demand for a shorter time interval between the conclusion of earthwork construction and the beginning of paving. This demand resulted in soils being placed in layers, in some instances moistened, and compacted, by either hauling equipment or rollers, to prevent the occurrence of settlement. Controversy often arose over what constituted adequate compaction under the requirement "thoroughly compacted", "thoroughly rolled", or rolled "to the satisfaction of the engineer". This resulted in demands for controls for use in checking the results of the contractor's operations in highway construction.

The quest for the knowledge and understanding of soils to conquer the problem of whether soils were adequately compacted was begun in 1929 by the California Division of Highways. Farmers and engineers have understood something of the effect of soil moisture on compaction, for depending on the season, they were aware that soil was often too wet or too dry for good results. However, prior to 1930, there is no literature to show to what extent this knowledge existed. The California Division of Highways conducted a series of tests which eventually developed field equipment and methods to consolidate soil samples, to determine moisture requirements before construction and, subsequently, the relative compaction of the completed embankment. Because the results of these tests were never published in literature having nationwide coverage, this beginning of the idea of soil testing was delayed until 1933.

The first series of studies that gained nationwide recognition and whose results are used to this day were conducted by the Bureau of Waterworks and Supply of the City of Los Angeles during the construction of an earth dam. The Bureau's findings were published by R. R. Proctor in August of 1933. The resulting method for determining moisture - density relationship bears his name.

This was the beginning of a search for knowledge. This beginning has grown to a science - Soils Engineering. Soils Engineering exerts its influence upon all phases of design and construction of civil engineered projects throughout the world.

## SECTION E201 – CLEARING AND GRUBBING

**E201.01 General.** This work consists of clearing, grubbing, removing, and disposing of all vegetation and debris within the limits of construction unless otherwise indicated, except such objects as are designated to remain or are to be removed under other Pay Items.

Before allowing the Contractor to work, the Inspector in charge should become familiar with all the requirements for this Section. The Inspector should have attended the preconstruction meeting held with the Contractor. The Contractor and the Inspector together should conduct a complete and thorough field trip to review and discuss all areas on the Project that require clearing and grubbing. The equipment that the Contractor plans to use should be discussed. The right-of-way provisions for the Contract should be reviewed carefully for any special treatment of items and areas that are to be left undisturbed.

The Contractor can not begin clearing and grubbing, or any other work, until it has installed all required erosion and sediment control measures. The Inspector should ensure that all erosion and sediment control installations are complete and in accordance with the Plans and Specifications before allowing the Contractor to proceed with clearing and grubbing. [110]

**E201.02 Undisturbed Areas.** The Inspector must ensure that the Contractor has plainly marked all areas, single items, or groups of items that are to be left undisturbed. These areas will be designated either on the Plans, in the right-of-way provisions, or by direct order from the Department. The Contractor will clearly mark trees that are to remain standing with flagging. [201.03]

**E201.03 Operations.** Contractors choose the equipment they use for clearing and grubbing. They employ a variety of equipment, although the use of bulldozers and power saws are the most common. The Contractor must not be allowed, however, to use equipment near structures that are to remain when such equipment might damage the structure. The Contractor should not be permitted to continue to use any equipment that gets poor results or delays progress. [108.06] The Contractor should completely dispose of all tree and plant growth removed during clearing and grubbing in accordance with the Specifications. All debris removed becomes the property of the Contractor unless otherwise specified. [201.04]

The Contractor must follow the Specifications regarding the filling of all depressions made after removal of tree stumps or other causes. [201.05]

Trees that are designated to remain but have been damaged must be satisfactorily repaired in accordance with the Specifications. [201.03]

### **E201.04 Clearing and Grubbing in Excavation Areas.**

- (a) *General.* All trees, undergrowth, and stumps, except those trees and shrubs designated to remain in place, should be cleared and grubbed. The choice of equipment is usually left to the Contractor as long as the equipment used will perform the work in a satisfactory manner. Occasionally, there are limitations to this choice of equipment dictated by the Specifications or common sense. For example, the use of explosives in congested areas should be controlled. If blasting is required or permitted, the Inspector should refer to Section E205 of this Manual for more information. [107.08]

The methods used to clear timber may vary from simply sawing a tree down to completely removing a tree, stump, and attached roots by pushing it over

and rooting the stump out of the ground with a bulldozer. The Inspector should study the requirements of the Contract closely regarding whether complete removal of trees is required or if cutting alone is permitted. The Inspector must then ensure that the Contractor follows the Contract requirements. The cost of tree removal has caused hand labor to be replaced by some very effective machines, such as the hydro-ax shown in Figure E-1. The Inspector must ensure that the Contractor furnishes competent equipment operators who will do the work correctly.

- (b) *Preservation of Trees.* Trees and shrubs that will not interfere with the use of a highway and its drainage system are often selected to remain in place for their scenic, historical, or other value. The Contractor must leave these trees and shrubs in place and must not damage them. Therefore, the Inspector must take some precautionary measures to protect these trees from damage during clearing and other construction operations. Clearly marking these trees will help preserve them. The Contractor may be required to remove low hanging and unsound or unsightly limbs from those trees that remain in place. This must be done in a manner that will not damage the remainder of the tree. Branches of trees extending over the roadbed should be trimmed to give a clear height of 20' (6 m) above the roadbed surface. All trimming should be done by skilled workers and in accordance with good tree surgery practice. **[201.03]**
- (c) *Extent of Removal.* Trees, stumps, and large roots should be removed from excavation areas to a depth that will satisfy the Specifications and prevent such objectionable material from becoming mixed with the material being incorporated in the embankment. **[201.05] [741.02]** These areas to be excavated will normally require scalping to remove small bushes, vegetation, rubbish, and other objectionable material. In addition, areas of heavy timber, undergrowth, and small trees may require root raking to remove the majority of the roots left in the ground after the aboveground portions are cleared. The Inspector should ensure that the Contractor's root rake sufficiently removes debris from the topsoil that is to be salvaged in accordance with Section 202 of the Specifications.



**Figure E-1: Tree Removal with Hydro-ax**

**E201.05 Clearing and Grubbing in Embankment Areas.**

- (a) *General.* All trees and undergrowth should be cleared and grubbed unless otherwise shown on the Plans or indicated in the Specifications. The general requirements listed in Subsection E201.04 of this Manual will usually apply to areas being prepared for embankment.
- (b) *Exceptions.* The Plans or Specifications may allow the trees to be cleared only in areas to contain embankments. That is, the trees and any existing stumps need not be grubbed out, but can be cut off as close to the natural ground surface as possible and left in place. This is normally allowed only in areas where the undisturbed stumps will be a minimum depth below the subgrade or side slopes of the embankment, as set forth by the Specifications. **[201.05]**
- (c) *Maintenance of Ground Surface.* All holes and ruts remaining below subgrades or sloped surfaces after clearing and grubbing should be backfilled and compacted as directed by the Engineer to prevent ponding of water. The cleared areas also require blading to provide positive drainage.

**E201.06 Disposal of Materials.**

- (a) *Chipping.* Chipping is probably the most popular method for disposing of clearing and grubbing debris today. The chipping equipment usually loads the chips directly into a truck for removal. If the chips are to temporarily remain on the project site, the location must be coordinated with the Contractor, subcontractors, and utilities. Chip piles should never remain for an extended period of time because the piles can self-ignite and may cause damage to adjacent properties.
- (b) *Burning of Timber.* DNREC and the Fire Marshall's Office have firm regulations regarding open burning. The Contractor must obtain approval from both of these offices before burning any timber. The following instructions are to be used only to the extent that they are not in conflict with the stated regulations and permits.

In areas where burning is not prohibited or where smoke will not present a problem, combustible materials such as trees, limbs, stumps, and brush are normally burned within the limits of construction. Burning within the right-of-way should be under the constant care of competent watchmen and accomplished in such a manner that everything designated to remain in the right-of-way, such as surrounding timber, grassland, and all other adjacent property, will not be injured. The Inspector should become familiar with all State and local fire ordinances and regulations in the area where the Project is located. The Contractor should notify the State Fire Marshall when considerable burning is about to commence. The Fire Marshall may place restrictions on the manner and timing of the burning. The Inspector should ensure that the Contractor understands the Fire Marshall's requirements. Notification must be given to the 911 office prior to any open burning.

- (c) *Disposal of Material Outside the Right-of-Way.* The Contractor is responsible for disposing of all material removed during earthwork operations. The disposal site must be approved by the Engineer before the Contractor may dispose of any material on that site. **[106.09]**

**E201.07 Clearing and Grubbing Hazards.**

- (a) *Blasting.* Blasting operations should always be conducted under careful, competent supervision to prevent damage to adjacent property and injury to people. The location of the area in which blasting is to be done will largely determine the procedure to be used. [205.04] Both the size of the area to be shot at one time and the strength of the charges set therein should be determined by the location where the blasting is to occur. Blasting charges, as a general rule, should be as light as possible, yet of sufficient strength to adequately break up the material being shot. In restricted or urban areas where the hazard to surrounding life and property is high, it may be necessary to load fewer, closer spaced holes with lighter charges to break the material while minimizing the possibility of damage. Newer, more sophisticated blasting methods can be used with larger charges as long as the method is approved by the Engineer. Blasting areas must be properly signed to inform all persons of the potential hazard and to ensure that all mobile radio units are turned off in the immediate vicinity of explosive charges. All explosives must be stored in a secure manner in compliance with local law and pertinent safety regulations. The Inspector should ensure that the safe distances and storage procedures stated in the Specifications are adhered to. [107.08]
- (b) *Tall Timber.* Clearing and grubbing operations, particularly in dense, tall timbered regions, can be very dangerous. Department personnel on the Project should be especially careful when working near clearing operations. Department personnel should make certain that the Contractor's operation does not endanger anyone working in the area, result in potential hazards to the traveling public, or damage existing facilities in or adjacent to the right-of-way. Extremely tall timber demands extra care and the proper equipment to get it on the ground without damage to surrounding property. Proper safety equipment, including hard hats and eye and ear protection, must be worn by the Inspector.
- (c) *Fire.* The type of area being cleared and the adjacent development should determine the manner in which burning is accomplished. Serious fires outside the right-of-way can develop if the Contractor loses control of the burning operation. Improper cleanup of the area surrounding the burning pile, a lack of watchmen to control the spread of the fire, and smoldering timber rekindled by high winds, are a few of the many causes of fire spreading beyond the intended burning area. There are many locations where it is advisable to use chippers, restrict the size of the piles, or select more favorable weather and ground moisture conditions before burning is started. Burning will never be permitted near or under utility lines. The piles should also be located within the cleared areas of right-of-way in a location that will prevent the spreading of fire to adjacent timber or other combustible materials. Adequate basic fire fighting equipment should always be available.

**E201.08 Measurement and Payment.** The Standard Specifications state that clearing and grubbing will be paid for at the Contract lump sum. The Supplemental Specifications and Special Provisions should be carefully reviewed for any exceptions to this method.

If additional areas beyond those indicated in the Contract must be cleared, no work should be permitted in the area affected until a price for this added work is approved and the area is measured and recorded.



## SECTION E202 – EXCAVATION AND EMBANKMENT

**E202.01 General Excavation Information.** This work consists of the removal and final disposal of all materials taken from within the limits of construction as necessary for the preparation and construction of the roadbed, embankments, subgrades, shoulders, slopes, sides, ditches, approaches, intersecting roads, and private entrances. Flexible pavement will be removed under this Section. The removal and final disposal of materials specified under other Contract Items is not included in this work.

Excavation and embankment work follows clearing and grubbing, and is one of the key operations in the construction of a graded roadbed upon which the base and wearing courses will be built. Excavation is the work to dig up and haul earth material from the right-of-way. The section of the roadway to be excavated is typically called a “cut” section. A portion of the excavated earth material is usually used to form the embankment portion of the roadbed. The embankment section of a roadway is typically called a “fill” section.

Roadway excavation, which is all material obtained from within the limits of construction, exclusive of pipe, channel, or structural excavation, may be composed of soil, solid rock, loose rock, or any combination of these materials. If there is not enough suitable roadway excavation together with suitable excess channel and structural excavation to complete the embankment to the required line and grade, then material must be imported to make up the difference. The imported material is called borrow. Under certain conditions, it may be necessary to obtain excavated earth material from under water. In this operation, a hydraulic dredge may be used to move the material into place. When the Contractor plans dredging operations, the Inspector should check the Contract to determine whether the Department or the Contractor is responsible for obtaining the proper permits to excavate in wetlands and then ensure that the permits have been issued before dredging operations commence.

Excavation involves loosening, digging, loading, hauling, and disposing of material obtained from roadway cuts, channel changes, ditches, structure foundations, and borrow pits. Disposal of the material is accomplished by incorporating it into an embankment or wasting the amount that is surplus or of an unsuitable nature. This item of work includes constructing, shaping, and finishing all earthwork for the entire length of the roadway, including the approaches, in conformance with the required lines, grades, and typical sections shown on the Plans, and with the Specifications.



**Figure E-2: Excavation in Preparation for SR-1 Construction**

**E202.02 Protection of Property.** The protection of property during excavation is a continuation of the practices initiated during the phases of right-of-way preparation and clearing and grubbing. There will be less restriction to the movement of equipment during excavation, and subsequent embankment construction, because the right-of-way will have been cleared and grubbed. However, in many cases trees must be preserved, and utilities and survey control points must be protected during excavation. Private property adjacent to the right-of-way must be protected from damage by the Contractor's equipment. Prior to beginning excavation, it is advisable to reemphasize protection of property to the Contractor.

**E202.03 Unsuitable Materials.** It is essential that the best possible use be made of the soil available for construction. Soils will be encountered that are unstable in their natural state because of excessive moisture content; however, many of these soils will respond to drainage improvement or mechanical manipulation to reduce the moisture content and render them suitable for use. Further, some soils are unsuitable because of their natural composition, and can cause instability in embankments. These soils should not be used and are normally wasted, unless an economical method of treatment is available to make them suitable. It may also be

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satisfactory to incorporate some less suitable soils in the bottom or lower center of embankments, where any detrimental effects will be minimized. Unsuitable material may also be used to flatten slopes.

If the planned grade is undercut for any reason, the amount undercut must be measured. The Inspector should cross section the undercut area carefully for the record. If the undercut area has been approved for payment, the record should be properly documented by the Inspector.

**E202.04 Salvaging Topsoil.** The Inspector's first duty is to check the Plans to determine the limits of excavation.

In areas where the excavated material in the deeper layers of the soil is not conducive to good plant growth, or will result in a slow rate of growth, it is a usual practice to strip off the upper surface (topsoil) of roadway cut areas, embankment foundation areas, and, in some instances, borrow sources. [732] The stripped-off material or topsoil is then stockpiled and used later to cover completed cut slopes, embankment slopes, and other disturbed areas where re-vegetation is desirable. [202.03]

The Inspector should determine the quality of the topsoil to be removed and salvaged. This determination may be done with the aid of the Materials and Research Section. If this material meets Specification requirements, the area may be cross sectioned before removal begins and again after removal is complete to determine the volume of topsoil removed. Alternately, the topsoil stockpile area may be cross sectioned prior to and after stockpiling. [202.10]

Topsoil must be stockpiled in an area where it will not be disturbed until it is ready for use. The stockpiled topsoil should not be in the way of construction operations. Assistance should be given to the Contractor in the selection of suitable stockpile areas that will minimize the haul involved and not interfere with or delay other construction operations during the progress of the work. The Inspector should pay close attention to the stripping operations. Although there may be no measurements required for pay purposes, the quantity being stockpiled and the manner in which it is excavated are important. Stripping topsoil too deep will easily yield the estimated quantity of topsoil, but may contaminate the topsoil with common material, thus reducing the quality of the topsoil. Conversely, shallow stripping will waste topsoil, reduce the estimated yield, and leave poor soils in the subgrade. An estimated total of stockpiled material should be maintained to ensure that enough topsoil is stockpiled before excavation for embankment construction is started.

Once all the salvaged topsoil has been stockpiled, the Inspector should ensure that the Contractor timely and correctly applies all erosion, sediment, and pollution control measures required by the Plans and Specifications. [110]

During the work to remove and stockpile topsoil (salvaging), the Inspector should calculate in embankment areas whether it is more economical to stockpile topsoil or leave it in place. Before calculating the economics of topsoil operations, consider the requirements of the Specifications. The Specifications state that for embankments less than 5' (1.5 m) high, all topsoil should be removed; however, for embankments 5' (1.5 m) or larger, the topsoil can remain. In areas of high embankments, the decision of whether to salvage topsoil or leave it in place should be reviewed. The following items should be considered in order to make an economical decision:

- (a) Know the quantity of topsoil required to complete the Project.

- (b) Compare the prices for topsoil and topsoiling in the Contract. **[732.10] [733.05]** If the difference is small, it may be more economical not to salvage the topsoil from the area.
- (c) Know the price for excavation. The Contractor will be paid for the removal of topsoil.
- (d) Know the price for borrow. The excavated topsoil must be replaced with embankment material.
- (e) Be familiar with DNREC regulations that apply to the Contract.

**E202.05 Cut Operations Checklist.** Before, during, and after cutting operations, the Inspector is responsible for the following:

- (a) Before any work is started, ensure that the area to be cut has been cross sectioned. If it has not, no work can proceed.
- (b) Before work is started, review the Plans to determine the limits of excavation, the depth of cut, the length of cut, the top and bottom of the slope, and any other details relative to the cut.
- (c) Ensure that all excavation is being accomplished in accordance with the lines, slopes, and grades shown on the Plans.
- (d) Ensure that all suitable excavated material is used in the formation of embankments.
- (e) Ensure that all unsuitable material is being disposed of as directed and that only unsuitable material is being wasted. Whether the disposal sites are designated on the Plans or procured by the Contractor, the Engineer will not approve the disposal site for use until details have been addressed. These details include a plan of the disposal area, proposed sediment and erosion control measures, existing and proposed final contours, and proposed security measures. Once the Contractor has submitted this information and the Engineer has approved it, the Inspector should ensure that the Contractor follows these details. **[106.09]**
- (f) Check the final condition of all cut slopes. Trees close to the top of the slope or trees with damaged roots should be inspected by Roadside Management for possible removal.

During this excavation phase of construction, it is important to observe the many factors that will affect the final condition of cut slopes. The two most important factors are water and rock. Underground springs or excess surface water will affect the construction. In rock cuts, the results of blasting and exposed unsuitable rock strata will affect final results. The Inspector should be alert to the following:

- (a) Any seepage in the slopes should be noted. This seepage should be kept under observation. If seepage continues or increases, engineering aid should be requested immediately from the District.
- (b) Erosion from excess surface water should be noted and observed, and a solution should be sought.
- (c) Cut slopes should be inspected from a safety standpoint. Loose boulders and debris should be removed when observed as a safety hazard, both during and after construction. Following blasting in a rock cut, the face of the cut must be carefully inspected for loose material, or for the uncovering of an unstable rock formation or strata. Removal must be considered from three standpoints: safety,

appearance, and economy. If any excavation work requires blasting, refer to Sections 205 and 206 of the Specifications.

Before acceptance, all cut slopes should be cleaned of loose rock, cleared of obstructions, and left in a neat, trimmed condition.

**E202.06 General Embankment Information.** This work consists of grading and compacting the embankment, roadway, and shoulders; construction, shaping, and sloping of side ditches, embankment, and cut slopes [202.05] [257]; construction and maintenance of temporary edge berms, interceptor berms, and embankment slopes associated with all erosion control methods indicated in the Specifications [258] [259] [260] [261]; undercutting, which is the removal of unsuitable material below the grade of a proposed subgrade or embankment foundation [212]; salvaging and stockpiling topsoil for re-use [202.03]; backfilling of areas from which unsuitable materials have been removed [201.05]; and the removal and disposal of all material not otherwise provided for [106.9], so that the Project is completed in a neat workmanlike manner.

The construction of an embankment is the most important operation in the building of a roadway. It is the fill part of cut and fill. The embankment can be a bridge approach of a few hundred meters in length or it can support a roadway several kilometers long. Regardless of the characteristics, every embankment is constructed using the same basic specifications that cover both the materials and the method of placement.

Embankments are constructed in layers, or lifts. Construction of every lift of material involves four steps: placing, spreading, grading, and compacting. The following Subsections give more detail on each of these steps, as well as other information related to embankment construction.

**E202.07 Soils Information Pertaining to Embankments.** Embankments are constructed of various types of soil. Some soil types are readily adaptable to embankment construction. Others are difficult to use and present many problems. Because of economic factors, most soils must be used, and the difficulties in adaptability must be overcome. Soil has been given scientific definitions by the farmer, the agronomist, the geologist, and many others concerned with it. However, the highway engineer can consider as soil any earth material that is encountered in the work, except embedded rock and shale.

The properties of soil that affect its workability and its usefulness will vary with its gradation or particle size, its moisture content, its vertical position in relation to the surface of the ground, and its geographical location.

The highway engineer has named the different particle sizes of soil and set definite limits for the size of each. In order that soils may be evaluated, it is necessary to devise systems or methods for identifying soils with similar properties, and then to follow this identification with a grouping or classifying of soils that will perform in a similar manner when their densities, moisture contents, and relations to water tables, climate, and other factors, are similar.

The primary purpose of soil identification is to describe a soil in sufficient detail to permit engineers to recognize it. The basic characteristics of soils indicate the mechanical and hydraulic properties that determine the suitability of soils for engineering use. The engineering properties influenced most by soil type are gradation and composition. It is possible to know, in a general way, whether a soil will be strong or weak, free draining or impermeable, if its gradation, texture, and classification grouping are known. The degree of compaction and moisture content in a particular soil most greatly affect its strength potential.



Soil surveys are made to obtain the necessary information concerning the types and extent of soils that will be encountered on a project. Representative soil samples are taken for analysis. The extent of the survey and the amount of sampling will depend largely on the size of the project and the character of the soils in the area.

The combined results of the tests by the Materials and Research Section will determine, among other things, the suitability of soils and the construction methods and construction equipment for the Project.

The requirements for borrow [209] must be followed, but for general guidance the Inspector should consider the following:

- (a) Borrow should be free from organic material, leaves, grass, roots, and sewage.
- (b) Borrow should be free from boulders and foreign matter.
- (c) Borrow classified as Types A, B, C, D, E, F, and G is recommended. If these classifications are not readily available, others may be used; however, special attention must be given to the method of placement and to the compaction of the embankment.
- (d) In general, granular soil, or soil with less than 35% passing a U.S. Standard 200 (75  $\mu$ m) screen, is desirable; however, in practice, the available material might be used.
- (e) No spongy, wet, or frozen material should be placed, and material should not be placed on spongy, wet, or frozen ground.

The materials specification for borrow to be used as embankment is extremely flexible; therefore, the burden of constructing a successful embankment is on material placement and compaction rather than on the material alone. Borrow may be any soil that does not contain organic material, leaves, grass, roots, sewage, boulders, or foreign matter.

**E202.08 Test Rolling.** Test rolling must be performed by the Contractor in accordance with the Specifications before embankment construction can begin. Test rolling is a loading test performed to evaluate the stability of subgrades and determine the limits of unstable areas that may exist. Test rolling must not be considered as a substitute for compaction tests that are used to measure the degree of density and moisture. The moisture content is, however, related to successful test rolling; that is, test rolling will reveal deficiencies only under certain moisture conditions. Test rolling also must not be considered a substitution for proper inspection, control, and testing during all construction stages.

Test rolling is usually performed with a loaded, ten-wheel, dump truck, although other equipment can be successfully used when the principles of test rolling are understood and applied. Other equipment may be used only if permitted by the Specifications. The equipment should provide a load that will equal or slightly exceed the load on the subgrade of the finished roadway when opened to traffic. The Inspector should fill out the Test Rolling Record form, shown in Part H, to document each test. [202.02]

The following are possible observations that may be made during test rolling, along with the corrective action to be taken (assuming proper loading):

- (a) If the moisture is within the proper range and movement is observed, the subgrade should be investigated and the cause determined. If no movement is observed, the subgrade is acceptable.
- (b) If the moisture content is excessive and movement is observed, the moisture content must be lowered and the test rolling repeated.

- (c) If the moisture content is low, it must be increased before proceeding with test rolling. Otherwise, a false impression of stability could result and future movement or settlement may occur.

**E202.09 Preparation of Embankment Foundation.** Prior to beginning the construction of an embankment, the area to serve as its foundation should be carefully inspected. All locations of questionable supporting capacity should be given special attention. The presence of soft or very wet conditions may suggest the need to remove unsuitable material, install underdrain facilities to remove spring or seepage water, or aerate and dry the materials that have become saturated due to poor surface drainage. Conditions of this type should always be called to the attention of the Engineer for decisions concerning appropriate action.

The Plans and Specifications should be carefully followed in preparing the foundations for embankments that are to be constructed through swamp, marsh, and old lake bed areas. Special construction methods are usually required in these cases and are generally worked out during the design stages for a particular project.

When constructing embankments on steep slopes, particular attention should be given to obtaining a good interlock between the sloping foundation and the new embankment. Proper interlock between the surfaces can usually be provided by benching into the old ground surface. This method consists of cutting benches into the existing ground slope as each successive layer of embankment is placed. This bench area, compacted with a layer of embankment, is then covered with the next lift of loose embankment material. Then, as a result of the kneading and compaction that follows, the embankment lift is keyed into the adjacent natural ground. This method of keying the new embankment to the original surface should also be employed when widening or raising the grade of old embankments.

**E202.10 Embankment Placement.** The importance of uniformity in embankment construction cannot be overemphasized. Construction methods that ensure, to the extent economically feasible, uniformity of material, layer thickness, moisture content, and compactive effort are vital in the accomplishment of proper embankment construction. The amount of inspection needed to secure proper construction will depend primarily upon the size of the Project, the nature of the soils, the rate at which material is being placed, and the Specifications.

The proper breakdown of clods and blending of materials is essential to obtaining proper embankment consolidation. The use of disk plows, blade graders, or similar equipment ordinarily will accomplish the desired result in most soils; however, the use of mechanical pulverizers may expedite the work of processing some of the very plastic clays for compaction. When it is necessary to place unlike materials in the same embankment layer, care should be taken to use equipment and methods that will provide a satisfactory blend of these materials. The result of the blending should be a mixture that can be uniformly compacted after moisture has been applied using a uniform rate of application. When feasible, poorer materials should be used in the lower portion of the embankment.

Prior to beginning the construction of an embankment, the location of the toe of slope should be clearly outlined by construction stakes. **[105.10]** Any staking that is done by the Contractor should be checked by the Inspector to ensure that no stakes are disturbed or destroyed. Stakes that are disturbed or destroyed should be reset immediately.

Wash outs, holes, and other low areas in the embankment foundations should be filled and compacted prior to beginning the construction of the first lift of embankment. The first lift of

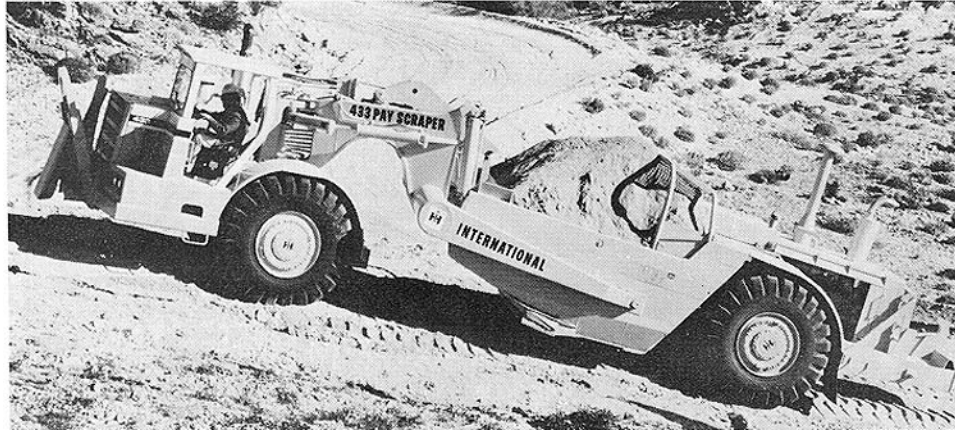
embankment should begin in the low areas and eventually provide an embankment layer approximately parallel to the finished grade. The first layer of material placed is considered a leveling course. Since the original ground is usually quite uneven, it may be necessary to permit the first layer of material to approach a depth of 12" (300 mm), loose measurement, at some locations. Good drainage and erosion and sediment control must be maintained throughout the construction period. Frequent checks should be made to see that the work conforms to the proper cross-section, all drainage and erosion and sediment control facilities are open, and the embankment site is in the best condition possible to provide maximum runoff. The Contractor should be encouraged to construct embankment slopes wider than designed to obtain the required compaction throughout the embankment section. The material beyond the designed slopes must be reclaimed and placed within the section limits for payment purposes. This procedure should also reduce erosion on the final slopes. **[202.05 (c)] [110]**

The selection of the equipment used to haul the embankment materials is usually left to the Contractor; however, the Contractor should not be permitted to operate the equipment in such manner that will be harmful to any existing or newly completed roadway. **[108.06]** The soil may be spread with the hauling equipment, or it may be spread by the use of blade graders, bulldozers, or other acceptable equipment.

The use of the rear-dump type of truck is common practice for depositing material. The material is end-dumped in piles across the roadway. The piles are knocked down and spread by bulldozers in the direction the fill work is progressing. Since the material is dumped in piles and spread, lift thickness is difficult to maintain. This type of operation results in the following disadvantage that must be corrected by the Inspector. The trucks used for this method may vary in capacity from 10 to 13 yd<sup>3</sup> (8 to 10 m<sup>3</sup>). In comparison to other hauling equipment, the capacity of these trucks is small. More specifically, their wheels and tires are designed for highway use and are relatively small. Truck drivers have a tendency to "follow the leader," that is to ride in each other's track in a single file line. This is fine for the highway but must be discouraged on the fill. These trucks must be routed over the fill in a manner to prevent serious rutting. Vigilance on the part of the Inspector will prevent fill damage in this manner.

Embankment placement may involve the use of a tractor-drawn or self-propelled scraper, or "pan." The use of this equipment is generally limited to the cut and fill type of operation. Depending on the type of material, and the power and size of the equipment, these scrapers are either self-loading or push-loaded in the cut. The scraper becomes a carryall for the trip to the fill. The fill material is placed on the run. A skillful operator can spread the material close to any desired thickness. Though not as fast as the bottom-dump type of operation described below, the use of a scraper is fast and efficient. Placing embankment with scrapers should present no unusual problems to the Inspector.





**Figure E-3: Scraper Hauling Soil to an Embankment Site**

On larger earthwork projects, one is likely to find the large, bottom-dump earthmoving truck. These trucks are similar to tractor-trailer trucks. The capacities of these trucks range from 20 to 44 yd<sup>3</sup> (15 to 34 m<sup>3</sup>). Some types are suitable for both highway and off-highway use. Most models, however, are not permitted on roads or highways because of their size and weight. These are called off-road or off-highway vehicles. As their name implies, these trucks deposit their loads from hoppers or gates located in the bottom of the truck body. The driver of this type of vehicle is not just a truck driver, but a construction equipment operator. By selecting the appropriate gear to maintain a constant given speed, the load may be dumped on the run and left behind at close to the required thickness of lift. With very little effort, a bulldozer can quickly spread the material, reduce the thickness to within required specifications, and ready it for compaction.

The Contractor's concern is to dump the material in such a manner as to reduce the time and effort for spreading and grading. The Inspector's concern is to observe the spreading and grading and ensure that the lift thickness is correct before compaction begins. The surface of the layer should be graded to a level, uniform cross section, eliminating sharp depressions or changes in elevation that would affect uniform compaction. The spreading is usually done by a bulldozer, and the grading and smoothing is done by a motor grader. Construction hauling over expansive clays should not be confined to the same path but should be spread out over the entire width of the embankment to avoid ruts or over-compaction.

The rapidity of material placement requires that the Inspector make sure that the Contractor has available sufficient spreading, grading, and compaction equipment to handle the material arriving. The Engineer may order a change in the rate of fill placement to allow for these other operations to be completed. **[108.06]**



**Figure E-4: Embankment Construction for a Bridge Approach**

**E202.11 Rounding and Warping Slopes.** Landforms are the most conspicuous and enduring features of a highway. The more closely new grading simulates natural ground forms, the easier it may be to cover the new grade with vegetation and maintain it. If the new grade simulates natural ground forms, less erosion will take place, and the new grade will provide a pleasing appearance for travelers. Rounding the tops of cut slopes where the slopes meet the natural grade is normally shown on the Plans. The radius of the curve to be rounded is standardized, but may be modified to meet local conditions to help control erosion. Rounding throughout the length of the cut slope may be modified by using a longer radius as the height of the cut decreases in order to improve erosion control. When the Plans do not provide for the flattening of the cut and fill progressively as the heights decrease, it is generally possible to achieve this effect during grading operations.

A field interpretation of the Plans to provide adequate rounding and warping may often be accomplished by simply making one or two extra passes with a bulldozer. This is best accomplished during rough grading. If there is any surplus excavation material or waste material,

it may be advantageous to flatten fill slopes with this material or dispose of the material at the toe of slopes. There will be less of a need for maintenance in the future if more rounding, flattening, and warping of slopes occur during present construction.

**E202.12 Embankment Compaction.** Each layer of embankment must be compacted to the required density before the next layer is placed. Compaction is a critical phase of roadway construction. The Inspector for embankment placement has two major responsibilities for ensuring conformance with the Specifications: proper material and proper compaction. Control over compaction procedures by the Inspector is necessary to ensure proper and thorough coverage by the compaction equipment in order to obtain the required densities. **[202.05]**

Embankment soils must be compacted to densities that will provide adequate stability for the finished highway. Experience and the results of considerable research have provided a means for determining the desired in-place density for the various soil types. Ordinarily, non-plastic and moderately plastic soils are compacted to the highest practical density at or near the optimum moisture content. If it is not feasible to confine plastic soils to the lower portions of large embankments, control of over-compaction as well as under-compaction may be justified. With these soils, high densities obtained at low moisture contents are not desirable since swelling, loss of stability, and roughening of the finished pavement may occur after construction is complete.

In-place density tests for checking compaction will be conducted by the Materials and Research Section using the specified equipment and in accordance with the specified test procedures. **[202.05 (f)]** The Inspector should contact Materials and Research to coordinate the density tests.

The first compaction procedure must be a definite rolling pattern. Every layer should be rolled in exactly the same way. The efficiency of any unit of compaction equipment is lost if a definite rolling pattern is not used. The usual pattern requires the rolling to start at the edges and progress toward the center of the embankment. By rolling the outside edges first, a form is simulated, confining the compactive effort of the equipment within the fill so that the equipment performs at its top efficiency. This is especially true with all vibratory compaction equipment.

The average number of passes to achieve the required density will be determined from the soil density test results.

When density tests are not used to determine the acceptability of earthwork compaction because of unavailability of test equipment or for other reasons, the Inspector must use experience and judgment to determine when satisfactory compaction has been obtained. If the Specifications require that certain compaction equipment be used, the equipment must be inspected and approved prior to its use. The results of the equipment inspection are to be made a part of the Project records. Particular attention should be given to maintaining proper loose layer thickness, proper moisture content, and adequate coverage with the specified rollers. If the specified roller is suitable for the materials being used and is of the proper weight, embankments constructed in relatively thin layers at optimum moisture content will normally possess the required stability, and neither settlement nor swelling due to improper consolidation will be a serious problem. Proof rolling may be deemed advisable on some projects to determine if the equipment and methods being used for obtaining compaction are satisfactory.

**E202.13 Moisture Control.** Moisture control is an important factor to getting good compaction. The soil at the time of compaction must meet the moisture content requirements of the Standard Specifications.

To efficiently and successfully compact the soil to the required density, the moisture content must be within 2 percent of optimum. In the field, if it is noted that the soil is too dry and the moisture content obviously less than required, the Inspector must insist on the application of water. If necessary, the area should be disked or harrowed to distribute the moisture uniformly throughout the layer. If it is noted that the area is too wet, especially following a stretch of inclement weather, then the Inspector should not permit compaction to begin or continue until the area is aerated. The common method is to disc or harrow the area, or constantly turn the area with a grader blade, until the area is sufficiently aerated to bring the soil to the required moisture content.

Whenever it is necessary to blend moisture into very plastic clays, heavy plowing and turning of the soil will usually yield satisfactory results; however, in extreme cases, some type of mechanical mixer may expedite the work.

When adding water to a layer of material, care must be taken to avoid overlapping or gapping between successive passes of the water distribution equipment. Wet or dry streaks are undesirable and should be avoided. The equipment operator should be instructed to begin applying water on one side of the embankment and work progressively across the fill to the other side to avoid having wet or dry streaks in the center of the embankment. It is important to make several light applications rather than one heavy application of water.

If the proper amount of moisture is uniformly distributed throughout the embankment layer, rarely will there be any difficulty in obtaining satisfactory compaction, provided the thickness of the layer does not exceed the capabilities of the roller being used. The tendency to construct earth embankments at moisture contents on the dry side of optimum makes the task of securing uniform moisture distribution and satisfactory compaction more difficult. Usually, it is better to begin compaction with the moisture content slightly high or at optimum.

The mixing and blending of soils and water should be thorough. Large clods of soil must be broken up to ensure a uniformly moist condition.

If additional moisture is required in excavated material to achieve proper compaction, water may be added at the source of excavation or borrow, or on the roadbed. Prewetting of the material in the excavation area or borrow source may be used if it is practical. If feasible, given the soil type and water availability, watering may be done by flooding or irrigating the area. This is done not only to satisfy the need for additional moisture in the soil, but also because a more uniform distribution of moisture is usually obtained. In addition, machine manipulation of the soil on the roadbed is reduced by that amount that would have been used to incorporate added water into the soil.

Constant coordination is required between the Inspector and Materials and Research Section personnel to ensure control of materials, density, and moisture content.

**E202.14 Subdrainage.** Thorough attention to subdrainage is essential to the life of the road and will result in reduced maintenance costs. Should the Inspector suspect the presence of subsurface water in such quantity as to affect the stability of the roadbed, and corrective measures have not been provided in the Plans and Specifications, the Inspector should investigate the subgrade conditions and submit the findings to the District office for review. The District office may refer the problem to the Materials and Research Section. After investigation and subsurface borings,

the Materials and Research Section will make recommendations for the situation. The Materials and Research Section may recommend the installation of underdrains under some conditions and in some types of soil. For more information on underdrains, see Section E715.

**E202.15 Embankment Fill Pumping or Weaving.** Pumping or weaving of an embankment may occur for a number of reasons. Some common causes of this condition and solutions are:

- (a) The previous layer of material may not be sufficiently compacted. If it is believed that this is the case, call for a density test in the area. This test may require excavating 1 to 2 feet (300 to 600 mm) of newly placed material and conducting the test at the lower elevation in order to obtain accurate results. Suspend placement of additional material until the specified density is achieved and the area is stable.
- (b) The moisture content of the embankment may be too high. This usually occurs because of previous inclement weather. If it is believed that this is the case, suspend operations until the area is dried out sufficiently. Call for a moisture check to verify the decision for both suspension and resumption. In some cases, aeration may help; however, if there has been a long duration of inclement weather, only the surface will be aided by aeration. This is why maintaining positive surface drainage is essential at all times. **[202.05 (f)]**
- (c) The moisture content of the previous layer or of the incoming material may be too high. If it is believed that this is the case, suspend operations. Call for a moisture test to verify the decision for suspension or resumption. Aeration by disc harrow or scarifier will permit the lift to dry out sufficiently to achieve proper compaction and stability. If the incoming material is too wet, fill placement should be suspended until the material source is changed or the material is within moisture tolerance.
- (d) There is a change in the appearance of the material. If this is the case, check the new material to ensure that it is in conformance with the Specifications. It is possible that both the original and new materials used for the embankment are in conformance with the Specifications but are not compatible. Usually, if they are mixed by scarifying and blading, they will blend and stability can be achieved. Suspend operations if the material will not conform to the Specifications.
- (e) Infiltration of water from side slopes or adjacent properties may require the need for ditching or the installation of underdrain to divert the incoming water.
- (f) Leaking existing or new pipe joints near the pumping area should be thoroughly inspected and repaired.

**E202.16 Special Fill.** Special fill (Borrow Type B) is sometimes called porous fill. The material is usually used for backfilling muck and swamp excavation areas or areas of fill below high tide. Special fill is a granular material designed to be placed in water.

Material used for special fill consists of clean sand, crushed or uncrushed gravel, or crushed stone. It should be free from frozen material, wood, or any extraneous matter.

Special fill must be placed by end-dump method. The placing of special fill by the end-dump method requires some special attention. When placed by this method, the fill should be end-dumped at the advancing edge of the fill, in order to result in a stockpile of fill material that can support the weight of the placement equipment. The fill should be placed and spread in such



a manner that the fill along the center of the roadway is placed before the fill near the sides of the roadway. Again, the material must be placed slightly beyond the proposed finished slope to obtain proper density. Excess material should be removed and incorporated into the fill. The fill should be spread forward and to the sides to achieve maximum displacement of any soft material on the bottom of the area being filled. The fill should be spread by using a bulldozer to push the fill forward and downward. If inspection reveals unsuitable material accumulating at the toe of the fill, the Contractor should be directed to remove the unsuitable material to prevent it from becoming trapped in the fill.

After the special fill has been placed to the elevation indicated on the Plans, the entire surface should be compacted in accordance with the Specifications. **[202.05]** The Contractor should level and grade the fill in such a manner that it will drain and contain no water pockets.

**E202.17 Borings.** If borings are required to determine whether or not unstable embankment foundation material has been satisfactorily removed, or whether or not unsuitable material has been trapped in the fill, they are to be made during the operation of fill placement in the areas of swamp excavation. The borings should be made after the special fill has been placed and graded in any area and before overlying embankment material has been placed. The locations of borings will be determined by the Engineer as the Work progresses.

**E202.18 Rock Embankments.** The construction methods for placing embankment material consisting principally of rock usually will depend upon the size of the rocks and the amount of rock present. Ordinarily, rock embankments are constructed in layers extending over the full width of the roadway, with the layer thickness in conformance with the Specifications. **[202.05]** By exercising skill in handling, the coarse and fine materials can usually be distributed so that the voids created due to the various stone sizes will be filled with small stones or earth to make the embankment as dense and compact as possible. When material is placed in the fill by the end-dumping method, this work should be accomplished by dumping the rock on top of the layer being built and shoving it ahead and into place with a bulldozer. Allowing material to roll into place by dumping it over the edge of completed Work should not be permitted. Oversize rocks not suitable for placement in a layer should be broken down to the proper dimensions in conformance with the Specifications. **[202.05]**

When rock is present in the embankment material in considerable proportions, moisture control procedures are of little benefit, and density tests for checking compaction are not considered feasible. Heavy rollers frequently prove to be advantageous for achieving the required density, particularly when combined with vibratory rollers such as the one shown in Figure E-5.



**Figure E-5: Tandem Steel-wheel Vibratory Roller**

**E202.19 Final Grading of Subgrade.** Before preparing the roadbed or subgrade for placement of the pavement, the entire roadway should be carefully checked to see that the earthwork conforms to the required cross section and grade within the accuracy of the tolerances established by the Specifications. **[202.06]** Any unstable or soft areas should be corrected by aeration or by removal and replacement of the unsatisfactory materials. Areas that appear to be excessively wet should be investigated for seeps and other sources of water. If such conditions are found, the Inspector should inform the Engineer that a problem exists so that appropriate action can be taken.

**E202.20 Measurement and Payment.** Excavation and embankment quantity will be measured by the cubic yard (cubic meter). The volume should be computed as stated in the Specifications. Excess material generated from the Contractor's excavation operations may be stockpiled for later use. This material will be measured once during excavation, and the Contractor will not be paid any double-handling costs, such as costs to incorporate this excess material into embankments on the Project or for other uses. An exception to this rule is for material stockpiled on the Project from other sources. An example of such a source would be a utility company. This material will be paid as excavation when it is taken from the stockpile and incorporated into the Project.

**E202.21 Inspector's Checklist for Embankment Fill Operations.** The Inspector should be on the lookout for trouble in the following situations:

- (a) Oversized rock contained in the fill.
- (b) Questionable materials placed.
- (c) Material being placed in the embankment changes in color, contains roots or other organic material, or is in some other way different from the material approved for use in the embankment.
- (d) Improper type of compaction equipment used.
- (e) Compactor may have lost ballast.

- (f) Juncture between cut and fill (grade point).
- (g) Embankment fill activity is concentrated in one area.
- (h) Soil clogs the sheepsfoot roller or soil covers the steel-wheel roller.
- (i) Insufficient number of passes with the compactor counted.
- (j) Lift thickness excessive.
- (k) Moisture content insufficient or excessive.
  - (1) Insufficient moisture is indicated by surface cracking or powdering.
  - (2) Excessive moisture is indicated by pumping or weaving action.
- (l) Fill placement is adjacent to manholes, inlets, or similar structures where smaller compaction equipment may be needed.

### SECTION E203 – CHANNEL EXCAVATION

**E203.01 General.** This work consists of widening and deepening existing stream channels and waterways, reconstructing channel and stream configurations and locations, shaping and finishing channel and streambeds and banks, and backfilling old channels and streams. This work also consists of the disposal or the approved utilization of the excavated material.

Channel excavation is used for the relocation or improvement of waterways, whether a small stream or a navigable river. Occasionally, the Contract will specify channel excavation as a major item of work. In these cases, Special Provisions are usually written with detailed construction procedures.

Channel excavation is performed by land-based excavating equipment on small relocations and by dredges or other floating units on major waterway relocations. For either operation, the Inspector's primary responsibility is to see that the construction progresses in accordance with the Plans and Specifications.

During the construction of smaller projects, it is most important that drainage in adjacent areas is not disturbed or hindered by this excavation. The disposal of the excavated material, if spread in this area, must conform to the natural ground contour and not be allowed to wash back into the stream.

**E203.02 Excavation by Dredging.** This method is used when relatively large areas of marshland or swamp are to be excavated and require the removal of unsuitable foundation material such as marsh, swamp, muck, or other organic materials from either the limits of the roadway or other areas to be stabilized for foundation purposes.

The operation is usually performed by floating equipment, such as dredges or barge-mounted draglines or clamshells. The operation involves the removal of unsuitable material to a firm, hard, stable bottom. The depth of this excavation will be determined by the Inspector. The width of the cut will be as shown on the Plans. The slope of the cut will be determined by the cross-sections and the relative stability of the existing in-place material.

**E203.03 Disposal Area.** The disposal area should be predetermined by the Plans or by local arrangement before beginning construction. The Inspector must be thoroughly familiar with the location and characteristics of the disposal areas assigned for the Contract. [106.09] [204.02]



Revised: January 2004

**E203.04 Dredging Inspection.** The principal goal throughout channel excavation is to acquire a reasonably clean bottom. Clean means free of organic, unsuitable, unstable, or undesirable material. It is the Inspector's primary responsibility to see that this is accomplished.

The following are the Inspector's tools:

- (a) *Plans:* Thorough familiarity with the Plans will give the Inspector knowledge and understanding of the construction of the Project with specific information regarding limits of excavation.
- (b) *Boring Information:* If the dredging Inspector has experience in the interpretation of boring information, the depths of excavation in specific locations can be closely anticipated. This information will also aid the Inspector in identifying soil types during inspection of the discharged material.
- (c) *Sounding Line:* A sounding line or lead line is a device for measuring depth under water. It consists of a line graduated with plastic or leather tags in feet (100 or 300 mm increments), with a heavy sounding weight secured on the end. By using the sounding line, and knowing the tide elevation, the elevation of the bottom of the cut will be known.
- (d) *Tag Line:* A tag line is a length of steel cable that is secured at each end on land and drawn taut across the excavation. The tag line is set at a definite elevation and is used as the base for cross sectioning. Cross sectioning of swamp excavation is done with the combination of sounding line and tag line.
- (e) *Tide Gauge:* The tide gauge is a device for determining the elevation of the water level in tidal waters at any given time. It usually consists of a staff, stoutly constructed in tidal water. It should be graduated in feet (100 or 300 mm increments) for the tide range of the area.
- (f) *Probing Rod:* A probing rod is a device that can be used to determine the depth of cut and to determine the condition of the bottom. A probing rod can be made of 1 1/2" (37.5 mm) diameter aluminum rod in 10 to 12' (3 to 3.7 m) sections with provisions for coupling any number of sections together. The rod is graduated in either feet or 300-mm increments. The use of the probing rod tells the Inspector the following:
  - (1) *Depth of Cut:* By using the probing rod in the same manner as a sounding line, the depth of excavation can be determined.
  - (2) *Type of Bottom:* By probing with the rod, the Inspector can determine if the bottom is soft or hard. This may indicate to the Inspector that there is more material to be excavated.
  - (3) *Thickness of Material:* By exerting extra pressure on the rod during the probing operation, the thickness of the remaining soft material can be determined.
- (g) *Dredge Log:* A dredge log or dredge diary must be kept for each floating unit. This work will typically require shift personnel, because dredging usually proceeds on a 24-hour, 7-day a week basis. Each shift Inspector should make the following entries in the dredge log:
  - (1) Date and time
  - (2) Weather conditions
  - (3) Excavation progress
  - (4) Time and location of each sounding or probing

- (5) Depth and conditions found for each sounding or probing
  - (6) Length of time and reasons for all breakdowns or production delays
  - (7) All visitors to the operation, especially superiors
  - (8) All instructions received
  - (9) Equipment used and number of personnel working
  - (10) All unusual happenings not covered above.
- (h) *Personal Diary*: The personal diary of the Inspector should contain all of the important information that has been recorded in the dredge log. Pertinent information from this diary will be recorded daily in the Project Construction Diary by the Inspector.

#### **E203.05 Inspector's Duties.**

- (a) Interpret the Plans and enforce the Specifications.
- (b) Dredge inspection is continuous. Since dredging is a continuous operation, it is imperative that the Inspector stays on the dredge for the Inspector's entire shift.
- (c) Make periodic soundings and probings during the shift. It is the responsibility of the Inspector to ensure a hard, clean bottom. The equipment should not be advanced until the condition of the bottom meets with the Inspector's approval.
- (d) It is the Inspector's duty to maintain the dredge log and personal diary in the manner previously outlined.

The principal duty of the Inspector, as always, is to ensure quality work and good construction records for the Department. Channel excavation by dredging involves an unknown soil composition that cannot be seen. By proper and diligent use of the Inspector's tools, the work will be accomplished in a satisfactory manner.

### **SECTION E204 – MUCK EXCAVATION**

**E204.01 General.** This work consists of the removal and disposal of mixtures of soil and organic matter, commonly called muck. This work also consists of backfilling the area where muck is excavated.

Muck is removed because it is unstable and will not satisfactorily serve as a foundation for any construction. The removal of muck is usually accomplished by land-based equipment such as a clamshell, dragline, front-end loader, or bulldozer.

**E204.02 Muck Identification.** The Inspector should learn to recognize and identify the material to be removed. Muck has been described as:

Thoroughly decomposed organic material with considerable mineral soil material. Usually black, with a few fibrous remains. Odorous when dried or burnt. Found as deposits in swamps, peat bogs, and muskeg. Easily identified. May contain some sand and silt. (Seelye, Elwyn E., *Field Practice*, 2<sup>nd</sup> Ed., Wiley, New York, C. 1954.)

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The Materials and Research Section should always be alerted that poor material has been encountered and should be requested to take samples that are to be a matter of record regarding classification and location.

**E204.03 Muck Limits.** By thorough study of the Plans and a physical inspection of the Project site, the Inspector must become familiar with the limits of the excavation.

In order to determine the depth of excavation, the Inspector should use several resources. The Plans will give some indication of the depth. The plan view may show some general depth figures, and the cross sections will show the expected depth of excavation. A review of the boring logs for the area may be useful in this determination as well. The Inspector on the Project will make the final decision as to the depth of cut by observation. This observation will be made by visual and physical inspection. Visually, the Inspector can determine the difference between the unsuitable muck and the more stable material. Physically, the Inspector will probe the soil with a rod, stick, or other means to determine the depth of the more firm material. This type of inspection will result in the efficient removal of the muck.

**E204.04 Adjacent Contamination.** During the removal operation, the Inspector must ensure that adjacent areas of good material are not contaminated by the Contractor's excavating equipment or disposal vehicles. Spillage from muck operations must be removed from good areas, restoring these areas to their original condition. This restoration, if required, is included in the Contractor's original scope of work.

**E204.05 Dredging.** For information regarding dredging operations and the Inspector's duties, refer to Subsections E203.02, E203.03, E203.04, and E203.05 of this Manual.

## **SECTION E205 – ROCK EXCAVATION FOR ROADWAY**

**E205.01 General.** This work consists of bedrock and ledgerock removal for roadway that cannot be accomplished without either blasting or using rippers. This work also consists of the use or disposal of such excavated material and backfilling the excavation with suitable material.

Rock consists of bedrock, ledge rock, and boulders, usually found in Delaware in an overburden of soil. It does not include soft rock or rock shattered in its natural position that can be torn loose and moved by methods other than blasting and ripping. **[205.02]** Boulders having a volume equal to or greater than  $1/3 \text{ yd}^3$  ( $0.30 \text{ m}^3$ ) (slightly larger than a 55-gallon drum) will be paid for in accordance with the Specifications. **[205.06]** Boulders can sometimes be removed without blasting.

**E205.02 Limits.** In roadway construction, rock should only be removed within the limits shown on the Plans. This, in most cases, will include only the roadway, ditches, and slopes. There may be times, however, when deeper and wider rock excavation may be necessary due to the need for sight distance or other special purposes.

**E205.03 Special Cuts.** It may be desirable in deep cuts to leave slopes that are 4:1 or 2:1 (vertical to horizontal) standing if the rock left in place is stable. A 4:1 (vertical to horizontal) slope is objectionable, though, because it creates the illusion of overhanging rock, particularly if

it is very high. Generally, the reason for such steep slopes is economy. In such cases, the District Engineer should be consulted for changes in design.

**E205.04 Excavation Requirements.** Unless otherwise specified, excavation in solid rock should extend at least 6" (150 mm) below the subgrade. These cuts below grade should be backfilled with material that is in conformance with the Specifications. Isolated outcrops of ledge rock or portions of large boulders that are exposed should be removed to a depth of not less than 6" (150 mm) below the subgrade elevation. **[205.03]** Low areas caused by such removal should be backfilled with suitable material. Following the removal and replacement of unsatisfactory subgrade materials, the subgrade should be scarified and all deleterious material removed. Large stones should be broken down or removed from the top portion of the subgrade. The loose material should be brought to the proper moisture content and compacted. The stability of the roadbed and subgrade should be maintained as existing conditions may require until the pavement section is placed.

**E205.05 Blasting Checklist.** Before the Contractor begins any blasting, the Engineer must conduct a blasting conference with the Contractor. The Inspector should check with the Contractor prior to the conference to ensure that the Contractor will submit all the documents required by the Specifications. **[205.04]** During the conference, discuss the importance of exercising the utmost care in blasting operations to ensure landscape preservation and protection of abutting, private property. Defacing the natural features beyond the limits of the Project should be avoided. The Contractor should be told that it must exercise control over its drillers and blasters to ensure that holes are properly located and that they are not overloaded. The Inspector should ensure that the blasting contractor has a blasting license and a blasting permit for the Project from the State Fire Marshall's office.

The Contractor is responsible for safe storage and use of explosives; however, the Inspector should carefully observe and check the Contractor's methods for the safety of the public. The Inspector should become familiar with State and other laws governing the storage and use of explosives. Of particular importance, the Inspector should ensure that blasting caps are not stored in the same building with explosives.

When blasting in restricted areas, the Contractor should exercise careful supervision to prevent damage to adjacent and surrounding areas. Only light shots should be used simultaneously. All blasts should be smothered with mats. Local laws governing blasting must be observed.

The Department is responsible for informing area residents of pending blasting operations. In some cases, blasting will be announced in advance in newspapers and on the radio. In other cases, Department personnel will go door-to-door to inform residents in the immediate area of upcoming blasting operations. The Inspector should work with the Resident Engineer/Project Supervisor to ensure the necessary steps have been taken to inform people of blasting operations.

In open cut construction, no blasting should be performed outside the lines shown on the Plans nor permitted to be deeper than is necessary to prepare a satisfactory subgrade.

In the event blasting causes a scattering of material beyond construction limits, the area should be reviewed in the presence of the Contractor to determine a proper method of removing the material without further damage to the landscape. In the event abutting private property is damaged, and repairs are not promptly made by the Contractor, blasting will be suspended and

the Area Engineer/Construction Manager should be notified so that appropriate action may be taken.

**E205.06 General Blasting Procedures.** Blasting operations should always be conducted under competent, careful supervision in order to prevent injury to persons or damage to adjacent property. At the same time, this operation should produce material in conformance with the Specifications, when required, and leave the cut area at the correct line and grade. The spacing and depth of the drill hole, the explosive type and loading sequence, the method of firing, and related matters are conditions to be satisfied by the blasting experts. Each of these matters is dependent upon local rock conditions and the production equipment to be used. Good blasting technique can lower the Contractor's cost while producing material in conformance with the Specifications under relatively safe conditions. Poor blasting by unqualified personnel can be dangerous as well as causing excess overbreakage or failing to shatter the material enough for economical handling and placement. Consequently, the material resulting from the poor blasting will require additional drilling and shooting or approved splitting devices.

The spacing and strength of the blasting charges should be such that the actual blast is as light as possible, able to thoroughly break the rock, and results in reduction in size for economical hauling and placement. Overshooting is very undesirable. Overshooting can produce rock fractures beyond the intended line and grade that result in jagged slopes, uneven ditch grades, and possible future slides in the slope areas. Special care should be used in the blasting of material immediately adjacent to proposed slopes or ditch lines. In deep cuts through difficult material where slope smoothness is hard to obtain, it can be advantageous to drill slope holes parallel to the proposed slope. In these sloped holes, the charge is distributed along the length of the hole, instead of placing all of it at the bottom, and then detonated simultaneously. This method of blasting is called presplitting. Check to see whether this method is required by the Plans and Specifications. This presplitting is not intended to loosen and break up a great amount of rock but to shear a reasonably smooth plane along the proposed slope face. The rest of the rock in the cut is then shot and removed in a manner best suited to the material involved.

**[205.04]**

Blast holes should be spaced close enough to ensure good breakage for economical hauling, with charges as small as possible. This avoids flying fragments and loss of material.

There are two types of blasting powder used in this work: slow active (or slow burning) and fast active (or fast burning). Slow active, also known as black powder, is normally used in side hill work consisting of part cut and part fill. When properly handled, it is possible to shift much of the material laterally into its almost final position so that little handling is necessary.

Blasting should be performed by an expert. The blasting expert should have the ability to locate drill holes and have the knowledge of depth control. As a rule, charges will not exceed  $1 \text{ lb/yd}^3$   $0.6 \text{ kg/m}^3$ . In cuts, charges should be vertical. Spacing should not exceed the depth of the holes, a technique that contributes to a cleaner break. Horizontal holes do not normally result in a smooth face, but can sometimes be beneficial when used in conjunction with vertical holes.

**E205.07 Blasting Boulders.** Block holing is the most widely used method for blasting boulders or large blocks of loose rock. In this method, a hole is drilled approximately halfway through the boulder; a charge is placed, tamped, and fired.

Often, the contractor encounters boulders embedded in the earth that are too large to loosen or move with mechanical equipment. Loosening these boulders can be done by the

snakeholing method, in which a charge is placed in a hole drilled close to the underside of the rock. If the charge is well placed and large enough, the boulder may not only be loosened but shattered as well. In sensitive areas where blasting is not permitted, boulders are drilled and the hole is filled with a compound that expands and splits the boulder.

**E205.08 Use of Material.** Wherever and whenever possible all excavated rock shall be used in forming embankments. [205.03]

**E205.09 Measurement and Payment.** Roadway rock excavation is measured by cross section methods. The Inspector is required to carefully obtain or supervise the taking of these cross section measurements. Rock excavated more than 1 foot (300 mm) below the subgrade should not be measured, nor should backfill be used to compensate for over-excavation. Over-excavation will not be paid for. The Specifications limit the depth of payment to 1 foot (300 mm) below the subgrade limit shown on the Plans or laid out in the field on grade stakes. The 1 foot (300mm) limit is the maximum amount of removal that the Contractor can be compensated for. Any areas excavated below the 1 foot (300mm) limit will not be measured and paid. [205.05]

## SECTION E206 – ROCK EXCAVATION AND BACKFILLING FOR STRUCTURES AND TRENCHES

**E206.01 General.** This work consists of bedrock and ledge rock removal for structures and trenches that cannot be accomplished without either blasting or rippers. This work also consists of the use or disposal of such excavated material and backfilling the excavation with suitable material.

**E206.02 Excavation and Backfilling.** At times, foundations for structures are set on rock instead of soil. Any rock excavation associated with foundation work should be done as shown on the Plans or as directed by the Engineer. [206.03]

Rock foundations generally should be cut to the intended shape of the proposed footing. Rock foundations should not be smooth, but should be well keyed, stepped, or serrated. This is necessary to ensure that the footing does not move on the rock foundation when the structure is loaded. Rock foundations for structures are to be carefully examined by experienced Inspectors prior to concrete placement. [105.02]

When blasting is used to excavate rock, the work should be done in accordance with the Specifications. [205.04] The Inspector should ensure that all material that becomes shattered or loosened has been removed in accordance with the Specifications and the Engineer's directions. The Contractor may use excavated rock to form embankments where allowed in Section 202 of the Specifications. [206.03] Refer to Section E205 of this Manual for information regarding blasting.

**E206.03 Measurement and Payment.** Rock excavation and backfilling for structures and trenches is measured by the cross section method and paid by the cubic yard (cubic meter). Detailed limits of payment are discussed in the Specifications and should be reviewed prior to measuring rock removal for payment. It should be noted that the horizontal pay limits are different for pipes, gutters, and structures. No payment will be made for blasting beyond the

limits given in the Specification or for the material required to backfill the over-excavated area.  
[206.04] [206.05]

## **SECTION E207 – EXCAVATION AND BACKFILLING FOR STRUCTURES**

**E207.01 General.** This work consists of the excavation, removal, and replacement or disposal of all materials necessary for the construction of box and pipe culverts, pipe headwalls, bridge structures, bridge approach slabs, and other structures. This work also consists of placing and compacting backfill material; furnishing and placing shoring, sheeting, bracing, and cofferdams; and dewatering these areas, unless otherwise specified.

If a new structure is to occupy the site of an old structure that is to be removed under the Contract, special payment measurements must be considered. The old structure will probably be removed as a Contract Item paid on a lump sum basis. The preliminary cross sections for excavation for structures must be taken after the old structure has been satisfactory removed. This is important in order not to provide double payment for part of the work.

**E207.02 Excavation.** The excavation pit for a structure should be adequate to accommodate the structure to be installed, and provide sufficient space for working, forms and bracing. It is desirable to keep the size of the excavation as small as possible because undisturbed natural ground under and at the sides of the structure will provide better support for the structure. The undisturbed natural ground will also provide better support for the embankment to be constructed over it than backfill will.

**E207.03 Backfill.** Proper backfilling of structures such as box culverts, abutments, and retaining walls is essential to eliminate future settlement. Strict adherence to the Specifications with regard to lift thickness, moisture content, and density required should be maintained throughout the backfilling operation. Density tests should be coordinated through the Materials and Research Section.

**E207.04 Direct Bearing Foundations and Spread Footings.** When structures are designed to bear directly on soil or rock, it is important that the material on which the structure is finally placed is as good or better than the designer intended. When written records, such as boring logs, are available, the Inspector should study them prior to excavation. The Inspector should have full knowledge of the type of material expected to be encountered. As material is excavated, it should be studied and compared with the boring logs. When excavation to the planned depth has been completed, further construction should not be permitted until the bottom of the excavated area is inspected and approved by the Engineer. [207.03]

All structures are designed to be supported by a foundation that is expected to be capable of carrying a load equal to a predetermined allowable bearing capacity, expressed in pounds or kips per square foot (pascals). This bearing capacity will vary with varying soil conditions. The Inspector must verify that the existing soils encountered at the foundation level are consistent with what is shown on the soil boring logs. If the soil encountered is different, the Inspector should contact the Materials and Research Section before proceeding. This determination is one of the most important field decisions to be made when beginning the construction of a structure.

**E207.05 Excavation below the Grade.** Direct bearing foundations, if excavated below the planned grade, should be backfilled only with approved material. Backfill material may be subfoundation concrete or coarse aggregate, and must be in conformance with the Specifications. [207.05]

**E207.06 Cofferdams and Seals.** Cofferdams enclose the foundation area and allow foundation work to be completed in dry conditions. Cofferdams are usually not shown on the Plans, but are constructed when wet conditions are encountered during foundation work. When cofferdams are shown on the Plans, the Inspector should ensure that the Plans and Specifications are followed carefully.

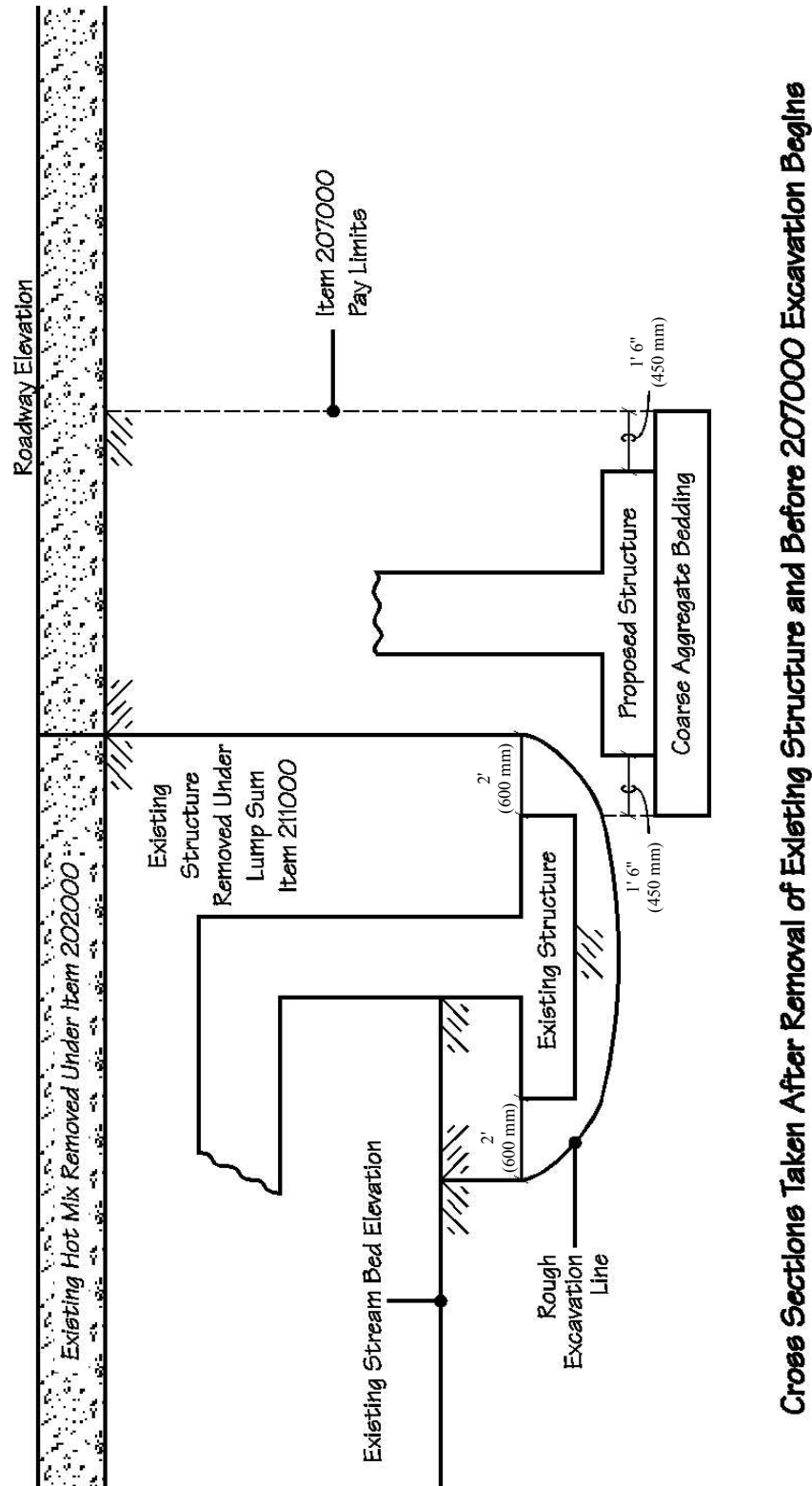
The Inspector should consult with the Engineer about requiring cofferdams if unstable soil conditions exist. The cofferdam should be constructed tight, strong, and safe. The safety of the workers and the ultimate success of the structure may depend upon the proper construction of the cofferdam. The Inspector is cautioned that the Contractor may not wish to spend more money for safe and proper cofferdam construction; however, previous experience has shown that the additional cost is justified by the increased safety for the workers. The Inspector should ensure that the Contractor submits shop drawings for cofferdams in accordance with the Specifications. [105.04]

Tremie seal concrete may be required at the bottom of foundation work where the intrusion of water is difficult to control. Tremie concrete placement is an operation that requires experience and skill. Information regarding the proper placement may be obtained from the Department.

**E207.07 Measurement and Payment.** If excavation is involved in the construction of any structure, and the excavation is a Contract Item, the Contractor should not begin excavation until the Inspector is satisfied that the area to be excavated has been cross sectioned. The cross section data is used in earthwork volume calculations or the volume of material excavated. The best time to obtain these measurements is just as the Contractor is staking out each foundation area. The outer pay limits stated in the Specifications should be staked out and an elevation taken on each corner and line break on the perimeter of the proposed excavation. Elevations should be taken on the old ground at each of these points, plus full cross sections as required by the Inspector who will calculate the quantities of earthwork. [207.06] The average end area method will be used for calculations as specified.



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**Figure E-6: Measurement and Payment Limits for Excavation and Backfilling for Structures**

## SECTION E208 – EXCAVATION AND BACKFILLING FOR PIPE TRENCHES

**E208.01 General.** This work consists of the excavation, removal, and replacement or disposal of all materials necessary for the placement of pipes. This work also consists of placing and compacting backfill for pipe trenches.

If rock is encountered during this excavation, review the Specifications. [206.02]

**E208.02 Excavation.** The trench for a pipe should be at least 24" (600 mm) wider than the outside diameter of the pipe or the minimum specified width, whichever is greater. Trenches dug in stiff clay or other stable earth may have vertical sides. When dug in other types of material, trenches should have a slope gentle enough to counteract the tendency to cave in. A slope of 6:1 (vertical to horizontal) will normally be sufficient in firm earth if the trench will not stand open for a long period. When trenches are dug in less stable materials, the excavation should be supported by bracing, sheet piling, or a trench box to hold the sides of the trench in place. The Contractor is to follow all State and OSHA safety regulations. The excavated material should be placed far enough away from the edge of the excavation so that it will not flow back into the trench or cause the bank to collapse.

**E208.03 Backfill.** Excavated material should be inspected and tested by the Materials and Research Section to determine if it may be reused for backfill in conformance with the Specifications. If the excavated material cannot be used for backfill, it should be placed on the Project, if possible, in embankment areas or embankment slope areas. Only if it cannot be used anywhere on the Project should it be disposed of, and then only by permission of the Engineer. To obtain uniform pressure against the pipe or structure, the backfill material is to be placed in lifts 8" (200 mm) or less and thoroughly compacted. [208.04] Water may be added, if necessary, to bring the material to the optimum moisture content for maximum consolidation. To avoid displacing or unduly stressing the structure, backfill on both sides simultaneously.

During construction, pipe culverts are to have a berm of compacted material on each side of and over the pipe that is at least as wide as the diameter of the pipe. This compacted backfill should be at least 12" (300 mm) above the top of the pipe. Density tests are to be made as required by the Materials and Research Section. Materials with low densities are to be replaced. Care is to be taken when tamping material under the haunches of pipes so as not to raise the pipe above the intended grade.



**Figure E-7: Pipe Trench Compaction**

Pipe culverts are to be protected from damage prior to the use of any heavy equipment. At times, water may be used to facilitate the settlement of granular backfill. Water is never to be used to facilitate the settlement of granular backfill where conditions of liquid or semi-liquid pressure may be developed within the berm area.

A final inspection is to be accomplished after completion of a pipe installation. Preliminary and final measurements are to include remarks and reasons for increases and decreases in Plan quantities, causes of sub-excavation, sources and quality of backfill, compaction data, and unusual difficulties with installation.

**E208.04 Measurement and Payment.** Unless otherwise directed, the depth measurement should be taken from the top surface of the existing ground at the time of the pipe installation. This may not be the original ground line but a subsequent lower level produced from the activities of general excavation.

For areas of pipe installation having pipe trench excavation paid, the Inspector must take depth measurements as required along the alignment for payment purposes. A record should

be kept of the size of pipe installed in that trench. These notes will be transposed to payment quantities in the Estimate Book in accordance with the Specifications.

Unless otherwise specified, excavation of rock will be paid for under Section 206 of the Specifications.

No measurement for excavation and backfill for pipes under 24" (600 mm) nominal inside diameter will be made. Excavation and backfilling will be incidental to the bid price for the pipe. [612.11]

When trench excavation meets or reaches a catch basin or manhole, the limits for measurement and payment will be to the outside wall of the drainage structure. However, when a trench excavation reaches a structure that has a paid structural excavation limit associated with it, the measurement and payment limit for pipe trenches will terminate at the structural excavation limit. [208.05]

## SECTION E209 – BORROW

**E209.01 General.** This work consists of furnishing and placing additional material from approved borrow areas or other approved sources when suitable material available within the right-of-way is not sufficient in quantity for construction purposes. This work also includes all clearing, grubbing, stripping, or securing of the borrow source required to prepare the borrow area for cross sectioning and excavating.

The term borrow is applied to soil as it is related to construction. Borrow, usually obtained from outside the Project limits, is required to meet certain criteria dependent upon its intended use on the Project. Examples of such uses are embankment fills, foundations for pavements, surface material for shoulders, backfill for pipes, and other uses. Other materials, such as cement, asphalt, salt, and lime, can be mixed with borrow to improve various characteristics of the borrow material, such as stability. The operation of mixing borrow and other material is generally referred to as soil stabilization.

**E209.02 Borrow Placement.** Borrow is to be compacted to a specified minimum density. The Specifications usually require that borrow must be within a certain moisture range before being compacted. [209.07]

**E209.03 Quality Control.** All sources for borrow must be approved in writing by the Materials and Research Section prior to use. Continued approval is contingent on satisfactory performance of the borrow in the field.

The Inspector must become familiar with the character of the borrow material that has been approved and is arriving on the site. The Inspector should be alert to any changes in the appearance or workability of the material. Should such changes be observed, the Inspector must investigate the reason immediately and take immediate appropriate action. If the Inspector determines that the material is not in conformance with the Specifications, the borrow placement work should be stopped until proper material is again being delivered to the Project. The Inspector should ask the Materials and Research Section to verify that the material meets the Specifications before allowing borrow placement to proceed.

**E209.04 Original Cross Sections.** Following written approval by the Materials and Research Section to use the material in a borrow pit but before excavation is started, the surface of the

borrow pit area should be cleared and grubbed. The pit area should then be stripped of all unsuitable material, that is, material not in conformance with the Specifications. When this has been done to the satisfaction of the Engineer, the pit area will then be cross sectioned. Excavation may not begin until cross sectioning is completed.

**E209.05 Borrow Pit Control Procedures.** It is the responsibility of the Inspector to exercise control over the borrow pits. The control should be in accordance with Section 209 of the Specifications. **[209.05]** Borrow pits are usually paid as measured from their original position. Therefore, it is imperative that the Inspector maintains close control over the excavation operation to be certain that all materials excavated from these locations are used on the Project in accordance with the Plans.

When payment for borrow is based on measurements taken from the pit in its original position, the pit should be made secure by some physical control acceptable to the Department. The type of control should be governed by conditions at the site; it may consist of complete or partial fencing, earth berms, guardrail, or other physical barriers. A gate, chain, cable, or other acceptable device will be installed across the entrance to the pit and secured by padlock, and the key to the padlock will be retained by the Inspector once the security method is approved.

The Inspector should personally make spot checks of the borrow pit. These checks should be made whether material is being brought to the Project or not, whenever the pit is in an “open” condition. An open condition exists when the original sections have been taken and final sections have not been taken.

While hauling material to the Project, the pit should be checked several times a day. Things to check include site security, safety of operations, consistency of material, and impact on the surrounding environment. Hauling operations should also be checked at this time.

**E209.06 Borrow Control Procedures.** Pit control must be immediately initiated when excavation begins. Borrow pit tickets have been designed for this purpose. The tickets contain the following information: date, Contract number, pit name or number, type of soil, and signatures of the issuing and receiving Inspectors. The tickets are issued in duplicate and numbered.

An inspector is stationed at the pit during all hours the Contractor is hauling material from the pit. During all other hours, the pit is secured. As each truck is loaded, a ticket is made out in duplicate. The original ticket is given to the driver, and the copy is retained by the Inspector. When the truck arrives at the Project, the ticket is collected and signed by the Inspector. The original and duplicate tickets are matched and checked.

When approved by the Department, borrow can be measured by weight in accordance with the Specifications. **[109.01]** The Inspector should ensure that the gross vehicle weight is shown on the tickets. Refer to Subsection E209.08 for more information.

**E209.07 Progress Payments.** Progress payments for estimate purposes are no problem if weight tickets are being used. If borrow is being measured by cross section, however, and tickets are not being used, then a careful load count must be maintained from start to finish. The load count should be recorded in the Inspector’s diary. For progress payments, the count and the adopted unit load figure (usually in compacted yd<sup>3</sup>/truck load (m<sup>3</sup>/truck load)) should be checked each time an area is completed. For example, multiply the number of truck loads by the unit load

figure to get the total number of cubic meters of borrow. Compare the calculated volume of borrow to the volume given on the Plans for a particular station count.

**E209.08 Measurement and Payment.** Borrow material can be measured by cross sections taken at the source in its original position, by weight ticket if requested by the Contractor in writing and approved by the District Construction Engineer, or by templating. If the material is coming from a State-owned pit, then the cross section method can be done. However, since most pits are privately owned, the easiest way to pay is by weight ticket. The Inspector receives the weight ticket from the Contractor and must convert the weight shown on the ticket to a volume using the appropriate conversion factor established by the Materials and Research Section for the specific pit that the material was excavated from. The gross vehicle weight (GVW) for each truck must be shown on the ticket to ensure that the truck is not over-loaded. **[105.12]** No payment will be made for any load that does not have the GVW shown on the ticket. This conversion method should not be used if it is believed that the Contractor is wasting material on the site or deliberately over-excavating to receive payment for the material to fill the over-excavation. When this situation occurs, borrow should be measured by either cross sectioning or templating. **[209.09] [109.01]**

At the end of the Project, when all borrow material has been removed and the cross-section method is being used, final sections of the pit are taken to determine the quantity of material excavated. The final payment amount is based on average end area computations. Final computations are made by the District Survey Section Head and the pay figure is given to the District Engineer by means of a letter.

Final cross sections must be taken as soon as possible after all of the borrow material has been obtained. It is the responsibility of the Inspector to see that the cross sections are recorded in the source document book.

Payment for borrow furnished under Section 207 and 208 of the Specifications will in no case exceed 1.3 times the volume determined, in accordance with Subsection 207.06 and 208.05 of the Specifications, less the volumes of the structure or pipes.

## **SECTION E211 – REMOVAL OF STRUCTURES AND OBSTRUCTIONS**

**E211.01 General.** This work consists of removal, wholly or in part, and satisfactory disposal of all buildings, foundations, fences, structures, and other obstructions which are not designated or permitted to remain within the right-of-way. Not included are items that are to be removed and disposed of under other Sections of the Specifications. This work also includes the salvaging of designated materials and backfilling of resulting cavities.

All designated salvageable materials should be removed, without unnecessary damage, in sections or pieces that may be readily transported. These materials should be stored by the Contractor at specified locations within the right-of-way limits unless the Specifications require transportation and deposit outside the right-of-way. Steel structures that are removed and are required to be salvaged should have matching components clearly marked immediately prior to disassembly.

The Inspector should study all governing specifications before the Contractor proceeds with this type of work. If the removal is not a lump sum item and is to be paid by measurement, all measurements must be carefully made and recorded before work commences.

For structure removal in navigable streams, the U. S. Army Corps of Engineers must be consulted. Review the approved plans and permits for this work, which are a part of the Contract, and discuss the Contract requirements with the Contractor to ensure the Contractor's planned procedures are consistent with the Contract requirements.

## SECTION E299 – EARTHWORK TESTS

**E299.01 General.** The Inspector should have knowledge of the tests conducted by technical personnel. Test results will indicate whether the Project is being constructed in accordance with the Contract. Results of these tests are given to the Inspector; therefore, the Inspector should have some idea as to how these results were determined. The following is a brief description of these tests. Additional information concerning testing procedures can be found in the Materials Manual.

- (a) *Gradation*: The determination of grain size distribution, which is the proportion of material of each grain size in a given soil.
  - (1) *Procedure*:
    - a. Weigh the sample to be tested.
    - b. Shake the material through sieves having various size openings.
    - c. Carefully weigh the material retained by each size sieve.
  - (2) *Result*: Check the percentage of material passing each size sieve with the Specifications relating to gradation. **[813]**  
Refer to AASHTO T-88 for more information.
- (b) *Plastic Limit (PL)*. The Plastic Limit of a soil is the lowest water content, determined in accordance with the procedure specified in AASHTO T-90, at which the soil remains plastic. A plastic soil is one that is neither so dry that it cracks nor so moist that it flows freely.
- (c) *Liquid Limit (LL)*. The Liquid Limit of a soil is the water content, as determined in accordance with the procedure specified in AASHTO T-89, at which the soil passes from a plastic to a liquid state.
- (d) *Plasticity Index (PI)*. The Plasticity Index of a soil is the numerical difference between its liquid limit and its plastic limit, and is calculated as follows:

$$PI = LL - PL$$

A small PI, such as 5, indicates that a small change in moisture content will change the soil from a semi-solid to a liquid state. Such a soil is very sensitive to moisture. A large PI, such as 20, indicates that a considerable amount of water can be added to the soil before it changes from semi-solid to liquid. When the LL or PL cannot be determined, the soil is reported as NP.

- (e) *Moisture-Density Relationship Tests (See Nuclear Test Procedure)*: The moisture-density tests are compaction tests used to determine the density to which a soil can be compacted with various moisture contents at a given compactive effort. The results of these tests produce the maximum dry density and optimum moisture content. These tests can be interpreted to give considerable general information about the soil. Broadly speaking, the moisture-density relations of a soil are so important that the moisture content and density of a soil must be

known when a particular load or bearing test is conducted. Otherwise, it is difficult, if not impossible, to interpret the test results. The greatest density obtained in the test is termed the maximum dry density, and the corresponding moisture content is termed, the optimum moisture content. More detailed definitions follow.

- (1) *Procedure:* This test is performed by adding different amounts of moisture to a dry soil sample, compacting the soil with a specified number of blows from a specified weight of hammer. The compacted density and moisture content of the soil are measured. These values are then used to calculate the dry density of the soil. The test is repeated several times, and a graph is created that relates the moisture content to the dry density of the soil. The maximum dry density and optimum moisture content are determined from the graph. Refer to AASHTO T-99 for more information.
- (2) *Results.* The results of moisture-density tests are reported as follows:
  - a. *Optimum Moisture Content:* The moisture content in the soil at which a given compactive effort will produce the maximum dry density.
  - b. *Maximum Dry Density:* The dry unit weight of a soil obtained by a given compactive effort at the optimum moisture content.

Figure E-8 shows the test data and results from a typical moisture-density test.



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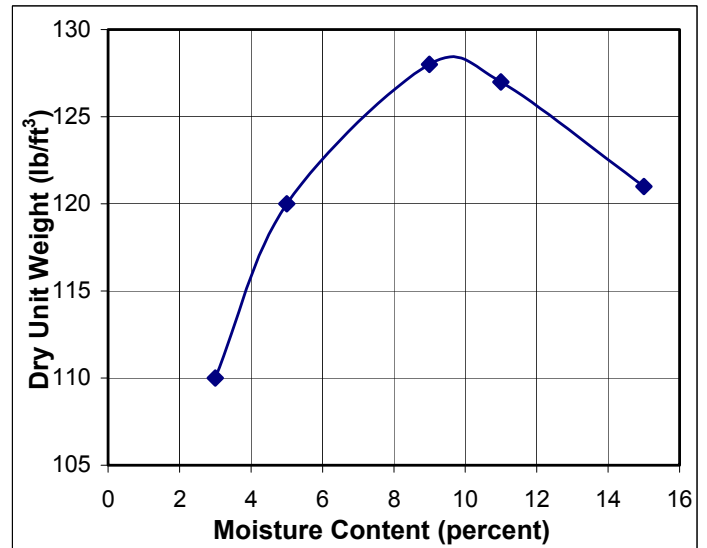
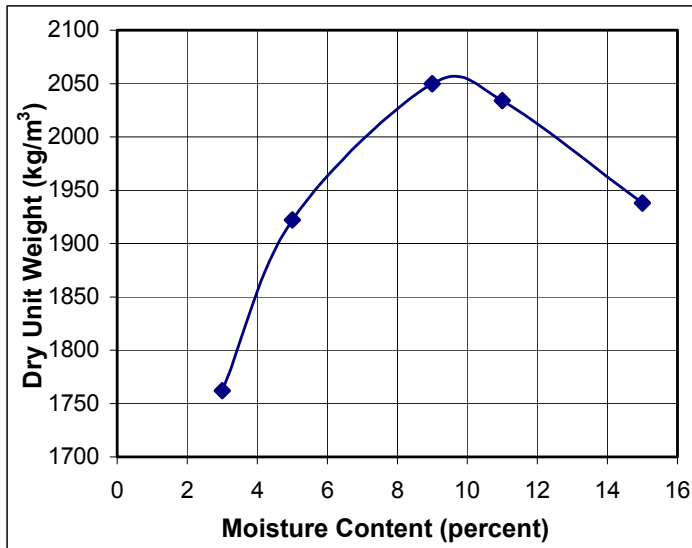
## Moisture-Density Relationship Test Results

**Project:** SR-1  
**Date:** November 10, 1998

**Location:** 1+500.000  
**Soil Type:** Silty sand

Moisture (%)	Dry density	lb/ft <sup>3</sup>	(kg/m <sup>3</sup> )
3		110	1762
5		120	1922
9		128	2050
11		127	2034
15		121	1938

**Maximum Dry Density:** 128 lb/ft<sup>3</sup> (2050 kg/m<sup>3</sup>)  
**Optimum Moisture Content:** 9%



**Figure E-8: Sample Moisture-Density Test Results**

- (f) *California Bearing Ratio*. Sometimes referred to as CBR, this test method is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than  $\frac{3}{4}$ " (19 mm). This test is used to evaluate the potential strength of subgrade, subbase, and base course materials to support loads. The detailed procedure and description of test equipment for determining the CBR is found in AASHTO T-193.
- (g) *Compaction Tests*. There are several methods for determining the in-place unit weight of soil. These test methods are outlined as follows:
  - (1) Disturbed method in which test hole volume is measured
    - a. sand cone
    - b. oil replacement
    - c. water balloon
  - (2) Undisturbed method in which sample is removed
    - a. drive sample
    - b. block sample
  - (3) Nondestructive method
    - a. nuclear (surface type)
- (h) *Delaware Compaction Test Practice*. The Materials and Research Section uses a nuclear gage to determine the in-place density of soil. This density can be compared to the maximum dry density determined in the lab to ensure that the soil in an embankment has been compacted in conformance with the Specifications. Refer to AASHTO T-310 for more information on the nuclear gage density test.

## DIVISION E300 – BASE COURSES

### SECTION E300 – GENERAL INFORMATION

**E300.01 General.** A base course is one or more layers of material placed on a prepared surface. A base course is constructed for three reasons:

- (a) To distribute the transmitted wheel loads to the embankment,
- (b) To provide a free-draining material, and
- (c) To provide a non-frost-susceptible material on which to support other base and surface courses.

Base courses are placed in various depth and width combinations, depending on the particular location and the existing soils conditions.

The depths and widths are shown on the Plans, but occasionally it may be necessary to modify the depths because of unforeseen conditions found after construction has started. It will be the duty of the Inspector to draw to the attention of the Engineer all conditions that appear to require changes in base course depths. [104.05] [105.02]

**E300.02 Materials.** Typical materials used to construct subbase and base courses are borrow, sand, gravel, crushed stone, slag, a combination of these, or other readily available granular type materials. They may either be pit run or processed, depending on the material available and the specification requirements. Subbase material might be obtained that would not require processing, whereas base aggregate, generally of a higher quality material, usually requires some form of preparation such as a screening or crushing.

The gradation requirements for materials used in a select borrow base course are outlined in the Specifications. Since gradation requirements are part of the Contract, it is imperative that the Contractor provides material that meets those requirements. Changes to the gradation requirements may be allowed only if they are justified and are approved by the designer and the Materials and Research Section. Any proposed changes in material requirements should provide a benefit to the State. [104.12] [301.02] [302.02] [304.02]

The Inspector must review the Plans, Specifications, cross sections, and the contents of this Manual prior to construction in order to be thoroughly familiar with all the requirements for materials, materials testing, test reports, and the scope of construction. The Inspector must ensure that all preliminary tests have been made and properly documented and that the proposed material will be acceptable when placed. Regardless of any difficulties the Contractor may encounter acquiring conforming materials, no base course will be accepted that is not in conformance with the Specifications. If substandard material is inadvertently placed, the Contractor should be instructed to remove or upgrade the material. In no instance should the Contractor be allowed to knowingly haul substandard material onto the work with the intention of later upgrading the aggregate in place. [106.08]

**E300.03 Sampling and Testing.** It is the responsibility of the Engineer to see that required samples are taken and tested prior to beginning construction. Sampling and testing of the proposed material will be done by Materials and Research personnel in accordance with *The Delaware Department of Transportation Materials Manual*. A sample Coarse Aggregate Report is in Part H. [106.02]

**E300.04 Placing.** Prior to placing the base course and after test rolling, the surface upon which the material is to be placed should be carefully examined. Check the surface with a sight level or stringline to verify that it meets grade. If soft spots, ruts, and grade deficiencies are observed, have the Contractor correct the deficiency by removing material, replacing material, or re-grading where necessary. The Contractor's personnel should develop a spread rate for the base course material prior to starting the spreading operation. The spread rate converts the tonnage of each truck to the number of meters along the centerline that that tonnage should cover. These computations should be checked by the Inspector. The spread rate should be based on the wet density at 2 percent or so above minimum density.

<i>Example:</i>	<u>ENGLISH</u>	<u>METRIC</u>
Maximum Density (Dry)	135 lb/ft <sup>3</sup>	2160 kg/m <sup>3</sup>
Optimum Moisture	8.0%	8.0%
Maximum Density (Wet)	146 lb/ft <sup>3</sup>	2333 kg/m <sup>3</sup>
Minimum Density (95%)	139 lb/ft <sup>3</sup>	2216 kg/m <sup>3</sup>
Target Density (97%)	142 lb/ft <sup>3</sup>	2263 kg/m <sup>3</sup>
Spread Depth	6 in	150 mm
Bottom Width	30ft	9.2 m
Top Width	26ft	8.0 m
Area	14 ft <sup>2</sup>	1.29 m <sup>2</sup>

$$\text{Spread Factor } 142 \text{ lb/ft}^3 \times 14 \text{ ft}^2 = 1988 \text{ lb/ft}$$

$$2263 \text{ kg/m}^3 \times 1.29 \text{ m}^2 = 2919 \text{ kg/m}$$

*So a truck with a 65,000 lb (30 000-kg) net load would cover a spread of 32.7' (10.28 meters).*

Once laydown has started, the Inspector should perform depth checks and width measurements in order to verify the computed spread rate. When the operation is fine-tuned to the point that plan dimensions are being achieved, the Inspector must consider yield. It is necessary to calculate as early as possible how well the yield, in, for example, stations per ton (metric ton), will match the contract quantity for the item, if the entire course is completed at the same rate. This information will bear on questions of project funding adequacy, materials source capacity, and any necessity to negotiate relative to significant variation from plan quantity.

The material should not be dumped in piles but should be spread by the use of a spreader box. The spreader box should be kept full. Precautions should be taken to avoid segregation of the material; that is, large stone should be prevented from separating from the fine portions. If segregation does occur, the Contractor will be required to remix the aggregate by blading, rototilling, harrowing, or other methods. **[301.05] [302.04]**



**Figure-9: Spreader Box**

The Inspector should be constantly alert during placement to detect changes in the appearance of the material so tests may be made immediately on the changed material. Oftentimes silt, clay, and organic matter inadvertently become mixed with the base material. If present, silt, clay, and organic matter should be removed from the base course material. An excess amount of these materials is detrimental to the base course since they increase the susceptibility of the material to the action of frost and reduce the strength of the base course when it is saturated with water. Constant vigilance accompanied by testing will help ensure that detrimental materials are not used. In addition, oversized rocks should be removed, since uniform compaction is difficult to obtain if they are present. Alternate freezing and thawing may tend to move the oversized rocks vertically, ultimately producing bumps in the finished road surface. [301.02]

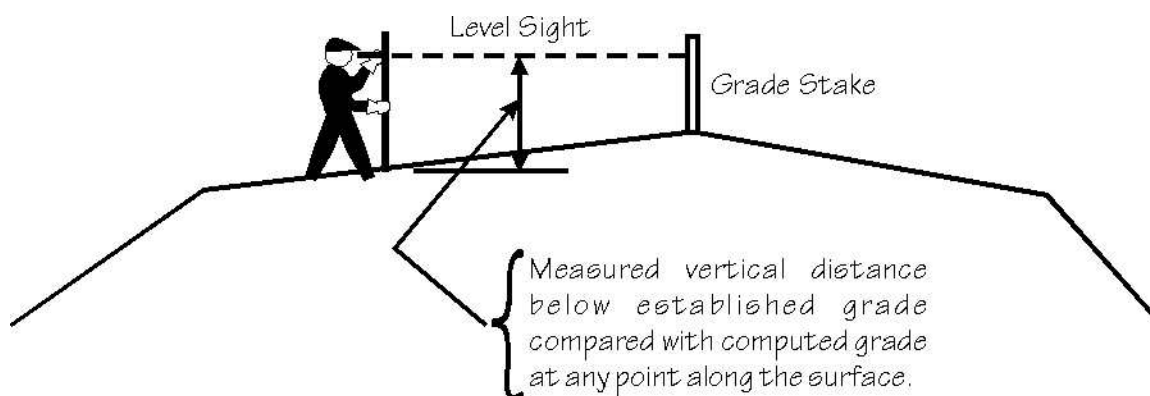
**E300.05 Checking Grade.** The final duty of the inspector regarding the inspection of the aggregate base course construction is checking the grade and shape of the finished aggregate surface. This can be done in one of several ways: (1) hand levels, (2) string lines, or (3) cross sections. Grades should be checked every 50' (15 m) on tangents and curves less than 16° and every 25' (7.5 m) on curves greater than 16°.

When using the hand level, the inspector sights through the tube at a known grade, usually marked on a grade stake, and measures the distance vertically from the level sight to the ground elevation. This distance is compared with the calculated distance as obtained from typical cross sections and grade elevations for the particular location being checked. Hand levels should not be used for sights exceeding a distance of 50' (15 m). Grades placed on stakes to be used for checking grade should be established with an Engineer's level and level rod by the survey party.

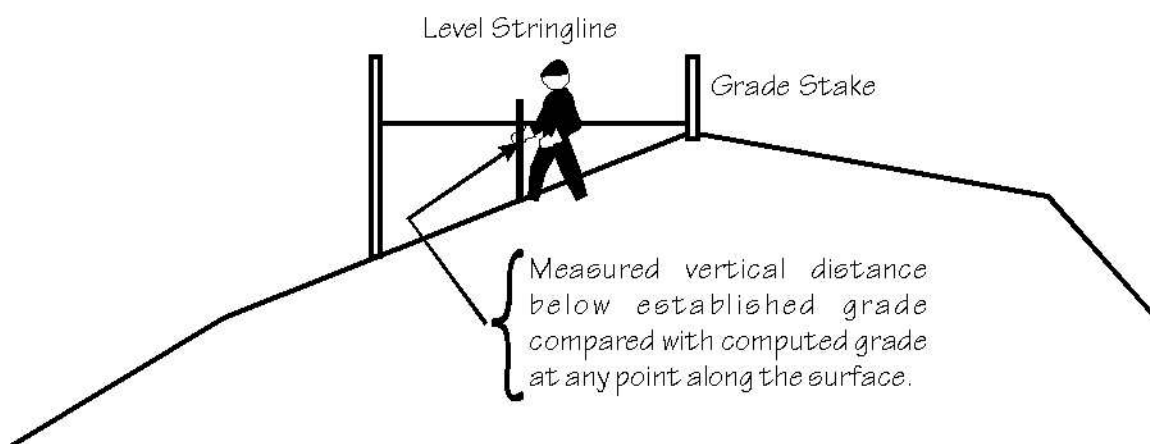
The stringline method is applicable when the distances are about 25' (7.5 m) or less. Shorter distances are preferable because they avoid errors that result from sagging of the stringline. After placing level grades or stakes across the road, a string is stretched between the stakes and the vertical distance at various points measured and compared to the computed dimensions.

Checking grades will be done by the use of an Engineer's level with a direct reading rod or a Philadelphia rod. The tape on the direct reading rod can be adjusted to read an elevation equal to the difference between the proposed profile grade shown on the Plans and the planned depth of the surface being checked. Then, the profile grade can be placed at various points on top of the finished base course and the profile grade can be read and compared to the grade shown on the Plans. Using the direct reading rod allows the base course grade to be checked without requiring calculations or note reduction. This method may be used on embankments, bases, subbases or any other course being placed that is to be parallel to the proposed profile grade.

Figure E-10E-10 shows the hand and stringline methods for checking grade.



*HAND LEVEL METHOD - GRADE CHECK*



*STRINGLINE METHOD - GRADE CHECK*

**Figure E-10: Methods for Checking Grade**

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**E300.06 Testing the Finished Surface.** The Specifications require that the finished surface of base courses not vary from that required on the Plans by more than  $\frac{1}{2}$ " (13 mm) when tested with a 10' (3.048 m) straightedge. The straightedge test consists of placing the straightedge on the surface of the compacted base course parallel to the centerline of the pavement. Next, the distance between the finished base course surface and the bottom of the straightedge is measured. If the distance is equal to or less than  $\frac{1}{2}$ " (13 mm), then the compacted surface is acceptable. If the surface is not acceptable, the Contractor must re-grade it and the Inspector must re-check it until it is acceptable. Note that the Contractor is responsible to provide a 10' (3.048 m) straightedge acceptable to the Engineer. **[301.06] [302.04] [304.04]**

**E300.07 Records.** Record keeping is a very important part of the Inspector's work. The Inspector's observations, measurements, and directions are the basis for supporting all parts of the work. Because much of the work is covered by subsequent construction, the results of the work cannot be readily reviewed later. Written reports and records of the Inspector's observations and measurements are usually the only remaining evidence that the work was performed correctly and that the State received the complete benefits of the Contractor's work paid for. Emphasis should be placed on recording all construction progress daily as it is performed.

The procedure to be used to document the base and subbase course construction follows:

- (a) The Inspector should make a written statement each time a series of grade checks is made. These statements should reflect the Inspector's work and findings. They might be of the following nature:

Checked grade Sta. 1+00.00 – 1+25.00; found it not to be within limits specified; more work needed.

Checked grade Sta. 1+50.00 – 2+00.00; found it to be within limits specified; gave Contractor go ahead.

Rechecked grade Sta. 1+00.00 – 1+25.00; found it to be within tolerance permitted by Plans and Specs; told contractor to go ahead.

All Statements should be recorded, dated, and signed on the appropriate form.

- (b) All notes and computations are to be retained and made a part of the Project records regardless of their form or condition. Make sure they get into the files.

Other records necessary to document this work include:

- (a) Soil Analysis Reports to show the quality of the material used. See Part H for an example.
- (b) Field density tests to show that the required compaction was achieved. This should also include tests for moisture content. Record the results on the appropriate form. See Part H for a sample field density form.
- (c) Measurements for final payment, such as cross sections, delivery slips, or in-place measurements as required. Record the results on the Inspector's Daily Report. See Part H for samples of the Inspector's Daily Report.

## SECTION E301 – SELECT BORROW BASE COURSE

**E301.01 General.** This work consists of furnishing, placing, and compacting select borrow material on a prepared subgrade. The information in this Subsection relates specifically to the

construction of a base course using select borrow. For information applicable to general base course construction, refer to Section E300 of this Manual.

**E301.02 Materials.** Prior to commencing base course construction, the Inspector should verify that the select borrow material the Contractor plans to use has been inspected, tested, and approved by the Department. [301.02] [106.02]

**E301.03 Equipment.** No special equipment is required to do the compacting of the select borrow material required for the base course. The Inspector should check, however, that the equipment is operating and being operated properly.

Machinery used to apply the compactive effort may be any one or a combination of the following:

- (a) Pneumatic-tired rollers,
- (b) Vibratory rollers,
- (c) Steel-wheeled rollers, or
- (d) Pan-type vibrating compactors.

The Contractor will usually be free to choose the type of equipment most adaptable to the material and work, subject to whatever requirements are specified in the Contract. [301.03]

**E301.04 Preparing the Subgrade.** The top of the earth embankment should be shaped to within 1/2" (13 mm) of the required grade and cross-section, and smoothed to provide drainage.

Make sure that the Engineer approves the completed subgrade so that the Contractor can begin placing the base course immediately.

**E301.05 Placing.** Before placing operations begin, the Inspector should review the planned construction operations with the Contractor. Make sure the Contractor plans its hauling so that truck traffic is distributed over the entire width of the surface. [301.04] [301.05]

**E301.06 Compaction.** Compaction should begin shortly after the base material has been placed. There are two factors that influence compaction:

- (a) The moisture content of the material, and
- (b) The compactive effort.

The moisture content at which compaction can be most easily obtained, with a stated amount of compactive effort, is referred to as the optimum moisture content. Laboratory tests will reveal what this moisture content is. (See Section E299.). If the natural moisture content of the available material is found to be low compared to the optimum moisture content, as it may be for granular material, water should be added. Water may be added either at the pit or stockpile, or after the material is placed. [301.05] The water may be introduced by:

- (a) passing the materials through a stationary plant and mixing them thoroughly,
- (b) adding it to windrows on the road and mixing by blading back and forth or rototilling, or
- (c) using a water truck with a spray bar.

In any case, thorough and uniform distribution must be obtained throughout the material. Moisture added to the surface aids only the material near the surface. The material at the bottom of the layer does not receive the needed moisture, and therefore ultimate compaction will be less at that level. This is why proper lift thickness is critical. [301.05]



The Specifications will state how much compaction will be required. The moisture content at the time of compaction is to be within 2 percent of the optimum moisture content. [301.06]

**E301.07 Measurement and Payment.** The Specifications state the method the Inspector will use to measure the quantity of select borrow base course for payment. Typically, the measure is the number of cubic yards (cubic meters) placed and accepted. Typically the quantity of select borrow base course will be measured by weight in tons (metric tons) and that weight is converted to cubic yards (cubic meters). [109.01] The factor used to convert weight to volume will be determined by the Engineer. If the Engineer can not develop a weight/volume conversion factor, then the factor given in the Specifications will be used. If the Contractor is wasting borrow material, then the Engineer will template the number of cubic yards (cubic meters) placed and accepted. [301.07]

The Inspector should review the payment subsections in the Specifications to understand which operations are included in this Item. [301.08]

## SECTION E302 – GRADED AGGREGATE BASE COURSE

**E302.01 General.** This work consists of furnishing, placing, and compacting graded aggregate base course materials on a prepared subgrade or base. The information in this Subsection relates specifically to the construction of a base course using graded aggregate materials. For information applicable to general base course construction, refer to Section E300 of this Manual.

**E302.02 Placement.** The Inspector should understand that the Specifications do not permit placement of any graded aggregate until the spreading and compacting equipment has been approved and the Contractor has brought the equipment on site and demonstrated that it is operational.

The only approved equipment for spreading the graded aggregate on mainline roadways are spreading machines and spreader boxes. Inspectors may not permit Contractors to use conventional motor graders or bulldozers to spread graded aggregate on mainline roadway construction.

The main concern when spreading graded aggregate base is that the material does not become segregated, that is, the fine material should not become separated from the larger material. Approved spreading equipment will help maintain the homogenous quality of material.

The Inspector should check the Plans and Specifications for depths of lift and compaction requirements. Note whether the depth of lift is given as a loose or compacted measurement. Also, note the limitation on the amount of material that may be spread ahead of compaction operations, as well as final grade tolerances. [302.04 (b)]

When water is added to the graded aggregate material, it should be done prior to compacting the lift. Water is added to bring the material to within two percent of the optimum moisture content. This moisture content is essential to good base course construction. Check to see that the added water penetrates the full depth of the lift. If the moisture content varies by more than two percent of optimum, then either additional water must be added or the material must be aerated. The Inspector should periodically ensure that the base material moisture content is within the specified range of optimum.

Compaction of the base material can be accomplished with either a vibratory or static steel-wheel roller. Vibratory rollers are more efficient for compaction of densely graded base materials. Static rollers are less effective for full depth compaction, especially at depths greater than 4" (100 mm). Rubber-tire rollers are useful in "sealing" the base course for asphalt treatment, if specified. Make sure that the Contractor doesn't over-roll the base course, as excessive rolling could "flush" fines to the surface, resulting in a poor bonding surface for asphalt or portland cement concrete courses.

Once the base course surface is compacted and on grade, the Contractor should be discouraged from hauling or allowing traffic on the completed base course prior to paving to prevent contamination by other materials.

**E302.03 Measurement and Payment.** The Specifications state how graded aggregate base course is to be measured. **[302.05]** Note that the method is different for select borrow base course and asphalt stabilized base course. Before measuring the in-place base course placed, the Inspector should review the Plans. Payment limits are designated on the Plans. Also, check the field records to see if the payment limits have been changed from what is shown on the Plans. Finally, the Inspector should record all field measurements taken and all calculations of quantities for payment. **[302.06]**

## SECTION E304 – ASPHALT STABILIZED BASE COURSE

**E304.01 General.** This work consists of scarifying, placing borrow, shaping the base course, stabilizing with asphalt, and compacting.

The use of asphalt stabilization of soils in road construction goes back over 40 years, as indicated by the following historical perspective.

### *Historical Perspective*

#### **Dirt Road Construction Program**

In 1955, the Legislature authorized a ten year Dirt Road Construction Program. The purpose of the program was to harden the surfaces of approximately 162 miles of dirt roads each year (if annual funding was made available). The Department developed techniques (for surveying, engineering, and construction) for implementing the large volume of work in an efficient and economical manner.

The present construction method consisting of a stabilized base with a surface treated wearing course is the result of the research. Presently, either an asphalt-stabilized base or a soil cement stabilized base is constructed. This section of the Manual emphasizes an asphalt-stabilized base. The general methods of construction described in this section have been developed to fit the majority of our Dirt Road Projects.

#### **Development of the Present Asphalt Stabilized Base**

Prior to the use of an asphalt stabilized base, the dirt roads were improved using compacted select borrow and three applications of asphalt and stone. Major problems surfaced, such as the completed roads showing evidence of rapid deterioration, and the select borrow became harder to locate. Problems similar to this generated additional research, which revealed that

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with the aid of an asphalt binder (such as AES3) certain gradations of common borrow would provide a highly satisfactory and durable subbase.

The depth of the stabilized base was not initially specified, however, in 1960 (considering the type traffic) a 4-inch base of compacted material was found to be sufficient. During 1962, the thickness of the sub-base was increased to 6 inches, with a 1/2-inch tolerance, due to the increasing volume of traffic and greater vehicular weights. The improved subbase was found to resist excessive moisture absorption, required less maintenance due to the freezing and thawing cycles, and was eventually more economical.

#### **Surveys and Plans**

As a further step in reducing costs, the Road Design Section has determined that extensive surveys and elaborate plans could be eliminated. This was accomplished by implementing field surveys, using vehicular patrols and preparing the plans in sketch form.

#### **Construction Inspection**

In part, the success of the Dirt Road Program lies with the expertise and judgment of the Inspector. The Inspector is usually the only State representative on the project working with the Contractor (except during the stabilization operation). The Inspector inspects all phases of the work and the materials used. The Inspector has the authority to reject materials or suspend the work until undesirable conditions are resolved.

**E304.02 Materials.** Three different materials are used in the construction of an asphalt stabilized base course. The Specifications state the testing required, if any, by the Materials and Research Section. The materials and applicable Specification sections are as follows:

- (a) Asphalt – Section 809
- (b) Water – Section 803
- (c) Soil – Subsection 209.04, Borrow Type E

**E304.03 Preparation for Construction Operations.** Prior to commencing construction of asphalt stabilized base course, the Inspector should become familiar with the requirements of Section 304 and the scope of work shown on the Plans. In addition, the Inspector should discuss the planned construction operations and review the items on the following checklist with the Contractor:

- (a) Work is scheduled between April 1 and September 30 only.
- (b) Materials have been approved by the Materials and Research Section.
- (c) The Materials and Research Section is aware of the construction schedule and can have personnel available to perform the required tests.
- (d) Appropriate equipment has been selected and is on the Project site: either two self-propelled mixers of the multiple-pass type or one self-propelled mixer of the single-pass type.
- (e) Contractor has available on the job an approved 10' (3 m) long straightedge.
- (f) Work is scheduled to start so that at least 2 hours of daylight will be available to complete the mixing operations following asphalt application.
- (g) The roadway has been shaped in accordance with the typical sections in the Plans.
- (h) The moisture content of the base course material is between 90 and 110 percent of optimum.

- (i) The asphalt temperature during application is between 140 and 160 °F (60 and 70 °C).
- (j) The Contractor has established a method to ensure the asphalt application rate remains between 14 and 20 gal/yd<sup>3</sup> (70 and 100 L/m<sup>3</sup>).
- (k) The Contractor has appropriately planned for a curing period of up to 14 days during which the base course will be open to traffic.
- (l) The asphalt truck is equipped with a measuring stick calibrated by the Materials and Research Section for measuring asphalt used.

**E304.04 Grading and Reshaping the Roadway.** Before stabilizing the base course, the roadway is usually widened, graded, shaped to the proposed typical section in the Plans, and ditches are cut. [304.04]

Materials encountered during the grading and reshaping operation that are unsuitable for the formation of embankments should be removed and disposed of by the Contractor unless otherwise directed by the Engineer. Test rolling is to be performed and documented prior to placing borrow. Areas that are unstable during test rolling are to be corrected in accordance with the Specifications. [202.02] [202.05] [304.04]

Undercutting is to be considered only after the Materials and Research Section has had an opportunity to analyze the material and provide recommendations.

**E304.05 Drainage.** During construction, consideration for the drainage of the base course to be stabilized is very important. The details for drainage of the base course are usually brief. The Contractor is to provide adequate drainage measures in accordance with the Specifications. The Inspector is required to ensure that adequate drainage is an integral part of the operation. The Inspector may be required to establish the grades and flows for the drainage ditches. The availability of a line level, Locke level, string line, and rule are important for this work. The ditches should be deep enough to establish a satisfactory drainage flow pattern. [304.04] [202.06]

**E304.06 Asphalt Sampling.** A random sample of the asphalt should be taken by the Materials and Research Section, for testing, for each 10,000 gallons (38,000 L) of asphalt used. The Inspector should coordinate this sampling. Each distributor of asphalt is to be measured by stick method upon arrival and departure. The Inspector is required to make frequent yield checks of the asphalt distributor and record the results of each check in the Project records.

**E304.07 Compaction.** The Contractor should ensure that the moisture content of the mix is within the limits stated above prior to compaction. When the moisture content is high, the compaction process may reveal pumping and cracking. If this occurs, the mixed material is to be aerated until the moisture content is reduced to the required range. In some instances, it may be desirable to postpone the final compaction operation for a day or two until the moisture is lowered by natural means instead of the aeration method. If the required density cannot be obtained, the problem may lie with the moisture content being too low. [105.02] [304.04]

Compaction should begin at the outward edges of the roadway and progress toward the center. The compaction phase should continue until the roadway is shaped and rolled to the satisfaction of the Inspector and in accordance with the Specifications. [105.02] [304.04]

The Inspector should be alert to possible compaction planes. These planes may develop when loose material is bladed onto a previously compacted base. When the top layer of loose material is compacted, it may form a separate layer of base material with little or no bond to the underlying layer of the base. Traffic, weather, or other forces acting on the roadway may eventually cause this upper layer to scale off and require considerable maintenance.

To minimize compaction planes, it is recommended that the underlying layer of the asphalt stabilized base be scarified approximately 1" (25 mm) deep. This may be accomplished by using a spike tooth drag or other approved method. The final compaction of the loose, bladed, material should then form a single, bonded layer of base material. [304.04]

After the required compaction has been obtained and the roadway conforms to the Plan profile and cross-sections, the roadway will be opened to traffic before sealing, on a temporary basis, to cure the stabilized mix. This curing period should not be longer than 14 days unless approved by the Engineer. [304.04]

**E304.08 Surface Treatment.** An asphalt stabilized base may be surface treated when its density, moisture content, and surface are in conformance with the Specifications. Refer to Subsections E404.10 and E404.14 of this Manual for more information on surface treatment of asphalt stabilized base course. [304.04]

**E304.09 Construction Testing.** During construction of the asphalt base course, the Inspector must coordinate testing by the Materials and Research Section. The Inspector must also ensure that the written record of test results is made a part of the Project files. The required tests are indicated in the Specifications. [304.04]

**E304.10 Measurement and Payment.** Note that two different types of measurements must be taken for this work. One is linear, in miles (kilometers), and the other is volumetric, in gallons (liters). The quantity of asphalt stabilized base course is measured linearly along the centerline of the roadway. The quantities of seal material and asphalt for stabilization are measured volumetrically by the "stick method," with payment for the number of gallons (liters) used through the distributor based on a temperature of 60 °F (16 °C). This measurement procedure is described below.

- (a) *Asphalt Measuring Stick.* The measuring stick should be of suitable material and sufficient length to extend from 1' (300 mm) above the hatch to the bottom of the distributor. It should be clearly and permanently marked in 1/4" (mm) increments, and it should be the property of the Department.
- (b) *Method of Measurement or "Sticking."* All distributors must be measured or "stuck" before applying the asphalt and again immediately after asphalt distribution is finished. The measurements must be taken by the Department inspection personnel and witnessed by the Contractor's distributor operator. It is imperative that the distributor is level and the temperature is accurately taken and recorded each time a measurement is made. All measurements should be taken to the nearest 30 gal (125 L), and the temperature to the nearest °F (°C). The Inspector should be aware of the potential for false readings due to foam on the asphalt surface or other conditions.
- (c) *Method of Recording and Computing Asphalt Quantities.* All information relative to the measurement and payment of each distributor load, or partial load, of

asphalt must be properly and completely recorded on an “Asphalt Distributor Ticket.”

The Contractor must furnish the Inspector with a copy, or copies, of the refinery’s original Bill of Lading for each lot of asphalt that was used on the Project. The Bill of Lading must always specify the type of asphalt, refinery, refinery tank number, refinery lot number, and the specific gravity. This information must be also placed on the Asphalt Distributor Tickets.

Upon measuring the depth and temperature of the asphalt in the distributor (both loaded and unloaded), the corresponding volume can then be converted to a 60 °F (16 °C) basis using the Asphalt Conversion Table (Table E-1).

In summary, the Asphalt Distributor Tickets must be filled out in full for each distributor load of asphalt, they must be signed by both the Inspector and the distributor operator, and copies must be forwarded to the District Office and the Contractor. The translucent copy of the ticket should remain in the pad for the Inspector’s information.

When calculating payment for this work, be sure to check the Special Provisions for any adjustment to the price of asphalt cement. **[109.13]**

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**Table E-1: Temperature (°F) Conversion Chart for Liquid Asphalt Emulsion  
(Applicable to Sections 304, 404, and 405 of the Specifications)**

<b>Temp</b>	<b>Factor</b>	<b>Temp</b>	<b>Factor</b>	<b>Temp</b>	<b>Factor</b>	<b>Temp</b>	<b>Factor</b>	<b>Temp</b>	<b>Factor</b>	<b>Temp</b>	<b>Factor</b>
40	1.0050	75	0.9963	110	0.9876	145	0.9792	180	0.9709	215	0.9627
41	1.0048	76	0.9960	111	0.9874	146	0.9790	181	0.9706	216	0.9625
42	1.0045	77	0.9958	112	0.9872	147	0.9787	182	0.9704	217	0.9622
43	1.0043	78	0.9955	113	0.9869	148	0.9785	183	0.9702	218	0.9620
44	1.0040	79	0.9953	114	0.9867	149	0.9782	184	0.9699	219	0.9618
45	1.0038	80	0.9950	115	0.9864	150	0.9780	185	0.9697	220	0.9615
46	1.0035	81	0.9948	116	0.9863	151	0.9778	186	0.9695	221	0.9613
47	1.0033	82	0.9945	117	0.9860	152	0.9775	187	0.9692	222	0.9611
48	1.0030	83	0.9943	118	0.9857	153	0.9773	188	0.9690	223	0.9608
49	1.0028	84	0.9940	119	0.9855	154	0.9770	189	0.9688	224	0.9606
50	1.0025	85	0.9938	120	0.9852	155	0.9768	190	0.9685	225	0.9604
51	1.0023	86	0.9935	121	0.9850	156	0.9766	191	0.9683	226	0.9602
52	1.0020	87	0.9933	122	0.9847	157	0.9763	192	0.9681	227	0.9599
53	1.0018	88	0.9930	123	0.9845	158	0.9760	193	0.9678	228	0.9597
54	1.0015	89	0.9928	124	0.9843	159	0.9758	194	0.9676	229	0.9595
55	1.0013	90	0.9925	125	0.9840	160	0.9756	195	0.9674	230	0.9592
56	1.0010	91	0.9923	126	0.9838	161	0.9754	196	0.9671	231	0.9590
57	1.0008	92	0.9920	127	0.9835	162	0.9751	197	0.9669	232	0.9588
58	1.0005	93	0.9918	128	0.9833	163	0.9749	198	0.9667	233	0.9585
59	1.0003	94	0.9915	129	0.9830	164	0.9747	199	0.9664	234	0.9583
60	1.0000	95	0.9913	130	0.9828	165	0.9744	200	0.9662	235	0.9581
61	0.9998	96	0.9910	131	0.9826	166	0.9742	201	0.9660	236	0.9579
62	0.9995	97	0.9908	132	0.9823	167	0.9739	202	0.9657	237	0.9576
63	0.9993	98	0.9905	133	0.9821	168	0.9737	202	0.9655	238	0.9574
64	0.9990	99	0.9903	134	0.9818	169	0.9735	204	0.9653	239	0.9572
65	0.9988	100	0.9901	135	0.9816	170	0.9732	205	0.9650	240	0.9569
66	0.9985	101	0.9899	136	0.9814	171	0.9730	206	0.9648	241	0.9567
67	0.9983	102	0.9896	137	0.9811	172	0.9728	207	0.9646	242	0.9565
68	0.9980	103	0.9894	138	0.9809	173	0.9725	208	0.9643	243	0.9563
69	0.9978	104	0.9891	139	0.9806	174	0.9723	209	0.9641	244	0.9560
70	0.9975	105	0.9889	140	0.9804	175	0.9721	210	0.9639	245	0.9558
71	0.9973	106	0.9886	141	0.9802	176	0.9718	211	0.9636	246	0.9556
72	0.9970	107	0.9884	142	0.9799	177	0.9716	212	0.9634	247	0.9553
73	0.9968	108	0.9881	143	0.9797	178	0.9713	213	0.9632	248	0.9551
74	0.9965	109	0.9879	144	0.9794	179	0.9711	214	0.9629	249	0.9549

## **DIVISION E400 – BITUMINOUS PAVEMENTS**

### **SECTION E401 – HOT-MIX, HOT-LAID BITUMINOUS CONCRETE PAVEMENT**

**E401.01 General.** This work consists of constructing hot-mix, hot-laid bituminous concrete bases and surface courses on either a prepared foundation or an existing surface course.

Hot-mix, hot-laid bituminous concrete is a mixture of mineral aggregate and bituminous binder heated and mixed in a stationary central-mix plant. The central plant-mix method permits closer control of moisture content, temperature, and mixture composition, which results in greater uniformity in the product. All types of plant mixes, whether open graded, fine graded, or sheet asphalts, are a type of bituminous concrete. All types of plant-mixed bituminous concrete have essentially the same mixing and placing procedures.

Bituminous concrete is composed of aggregate and bituminous cement. The aggregate is usually crushed stone, gravel, and mineral filler, and is well graded to ensure interlocking between the aggregate particles, which provides strength to the pavement. The bituminous cement binds the aggregate together and provides stability to the pavement. For more information on the materials used in hot-mix, hot-laid bituminous concrete, refer to the Specifications and Section E823 of this Manual. [823]

**E401.02 Paving Operations.** The construction of bituminous concrete pavement begins with the delivery to the roadbed of a workable mixture that has been proportioned and mixed in accordance with the Specifications. The pavement will be constructed of the type of mixture, number of courses, and at the depth specified for the Project. Prior to the delivery of the mixture, the surface on which the pavement will be placed is to be constructed to the correct grade and cross section, compacted to the density specified, and cleaned of all dirt and foreign material. [401.08]

**E401.03 Traffic Control.** The traffic control requirements for a bituminous concrete paving operation should be discussed in detail at the preconstruction meeting. Definite traffic control procedures should be established for the safety and convenience of both the traveling public and construction workers. Barricades and warning signs of the type shown on the Plans are to be furnished and erected by the Contractor at the locations shown on the Plans and designated by the Engineer. [104.09]

Paving operations normally are performed at a fast pace, with most of the traffic hazards concentrated around the paving area. Traffic should be directed through the construction area with warning signs, flaggers, and maybe even pilot vehicles. These traffic control measures should provide maximum safety for the people working in the area, a minimum amount of interruption to the paving operations, and safe passage for the traveling public. Lane closures are to be provided to keep traffic off the freshly sprayed tack coat or uncompacted bituminous concrete mixture. Traffic officers may also be required depending on the traffic volume and posted speed limit for the roadway being paved. The Contractor should ensure that all safety precautions are visible at night. [104.09] [108.05]

Avoid diverting traffic to shoulders during paving operations unless the shoulder box has been determined to be adequate to support the traffic load. If drop-offs exist during paving, the Contractor must mill or place a ramp sloped no greater than 6:1. The Contractor must also place a “Bump” sign at this location.



**E401.04 Weather.** During paving operations, the weather limitations described in the Specifications are to be followed. Plant production operations are to be suspended at the imminent approach of and during wet weather for all State projects. [401.08]

**E401.05 Inspector's Duties before Paving Begins.** The Inspector should be thoroughly familiar with the Plans and Specifications for the Project, and should have readily available the equipment necessary to check all phases of the paving operations. The paving sequence previously approved by the Engineer should be reviewed with the Contractor. An inspection should be made of the construction equipment to ensure that the number, size, and condition required by the Specifications are available and on the Project. The Inspector must feel assured that the contractor can place a minimum of 100 tons per hour (401.03) in order to maintain forward motion of the paver without stopping. Refer to Subsection E401.06 of this Manual for additional information. [401.04] [401.05] [401.06]

Prior to the start of paving operations, the Inspector should inspect the road surface on which the pavement is to be placed. Inspections should include verification of the correct grade and cross section. Work areas, depressions, and potholes should have been repaired to provide a firm, unyielding paving base. Should an existing surface require resurfacing, be sure the surface is clean and free of dirt and other extraneous matter, and that all weak areas are repaired. If a leveling course is to be applied, the existing surface should be inspected, and the roughest areas should be marked to receive a pre-level-up course during construction. A tack coat, when required, should be uniformly applied to all surfaces. The tack coat should be applied to the width and length required for one day's paving. Refer to Subsection E404.01 of this Manual for additional information on tack coats. [401.07] [401.08]

**E401.06 Inspection of Paving Equipment.** The Inspector should ensure that the condition of the Contractor's paving equipment and adjustments of the component parts and rollers are in conformance with the Specifications. Any deficiencies discovered are to be corrected prior to the start of operations to avoid delays once the work is under way. [401.04] [401.05] [401.06] The following are some of the more important details for inspection of the paving equipment:

- (a) *Hauling Equipment.* Trucks used to haul bituminous concrete to the Project must have clean metal beds that have been thinly coated with an emulsified asphalt or soap solution to prevent the bituminous concrete from sticking to the bed. The truck bed must be covered with a tarp securely fastened to the truck. Air flowing across the bituminous concrete while the truck is traveling to the Project site can cool the bituminous concrete, making it unacceptable for placement. Trucks hauling bituminous concrete between September 30 and March 31 must be insulated or, if approved by the Engineer, the truck beds may be heated. [401.04]
- (b) *Paving Machines:* It is strongly suggested that the Inspector become familiar with the mechanical features of the type of paver to be used on the Project. [401.05] The Inspector must be able to provide an appraisal of the condition of the equipment and ensure that the Contractor makes the proper adjustments to the machine. Handbooks of operating instructions are available from each manufacturer describing the various adjustments and operating details. The general features to be inspected are:
  - (1) All paving machines should be checked to ensure that the motor is operating smoothly and the governor is operating properly.

- (2) On crawler track machines, track linkage adjustment should be checked, and the tracks and pins should be inspected for excessive wear.
  - (3) Rubber-tire machines should be checked for proper inflation of the tires, the correct adjustments to the chain drives, and excessive wear.
  - (4) Tamper bars are to be checked for proper clearance from the screed, the correct vibration frequency, and the correct stroke length, and ensure that there is not excessive wear on the tips of the tamper bars.
  - (5) The transverse oscillating strike-off should not have excessive play and should have the correct adjustment from crown to hilt.
  - (6) The immobile foot in front of the screed should be checked for the proper height above the vibrating screed.
  - (7) Screed plates are to be checked for excessive wear, proper crown and tilt adjustment, and efficient operation of the screed-heating burner. Screed extensions are to be in the same true plane, and are to be flush with the screed bottom. The vibrators on the vibrating screed are to be checked for proper operation.
  - (8) Both manual and automatic grade or thickness controls should be checked for proper operation.
- (c) *Rollers:* Steel-wheel rollers are to be checked to determine whether the wheels are capable of rolling in a true plane and are free from flat spots or ridges. The steering and driving mechanism must be free of excessive play or backlash, and the motor and driving transmission must be free from oil leaks. Each roller is to be fitted with a water tank connected to spray bars and mats on each wheel. The wetting mats should be checked for excessive wear, and the spray bars should be checked for proper operation. **[401.06]**
- (d) *Miscellaneous Tools:* The Contractor should have available an adequate supply of lutes, shovels, brooms, and other small tools. The Contractor is also required to be properly equipped with drums, cones, or other approved devices that may be used for protecting the freshly laid mixture from damage by traffic. **[108.05] [108.06]**

The various types of equipment used for bituminous paving are discussed in detail in Division G400.

**E401.07 Spreading and Finishing.** The bituminous mixture is usually spread and finished by a self-propelled paver. In irregular areas, the mixture may be spread and finished by hand if permitted by the Engineer. **[401.08]**

The principal duty of the Inspector is to ensure that the Contractor constructs the pavement to the correct grade and cross section as established by the Plans, and with a surface texture and riding surface as described in the Specifications. To achieve these results, the Inspector must continually inspect the surface to be paved, the mixture in the trucks, the surface texture behind the machine, and the rolling operation. The Inspector is required to check the paved surface with a straightedge or stringline for proper slope and smoothness. The Inspector is also responsible for collecting load tickets and performing yield checks to ensure the proper mat thickness is being placed. Refer to Part H for a sample Hot Mix Yield Check form. **[105.02]**

Prior to starting paving operations, the Contractor should heat the screed to the proper temperature, and set the grade controls to construct the transverse joint. The Contractor should exercise care when setting the thickness control device to ensure that the desired spread and

crown will be achieved. The Contractor should have wooden blocks of various thicknesses available to place under the screed in order to obtain proper mat thickness. The Inspector should carefully check to ensure that the proper mat thickness and cross slope are set before the paver is allowed to begin. In addition, the Contractor should use paving equipment with electronic screed controls attached to a ski board not less than 30' (9 m) long. When beginning paving at an existing transverse joint, the paver should be set at a height slightly above the existing mat so that when the new mat is rolled both pavements will match with a smooth transition. The fresh mat will consolidate 20 percent during compaction. The Inspector should check the transverse joint by placing half the 10' (3.048 m) straightedge onto the existing mat and the other half onto the new mat. No deviations larger than 1/16" (2 mm) should be present. If this tolerance is not met, then the Contractor should not be allowed to proceed until the joint is corrected. **[401.05]**  
**[401.12] [108.06]**

When matching the edge of a previously laid section of pavement, the paver screed should overlap the existing edge from 1 to 2" (25 to 50 mm). In addition, the thickness control should be adjusted to leave the material slightly higher than the previously laid section of pavement. Overlapping this edge will force more than enough material into this area to ensure that the joint is completely filled and moisture proof. The height of the material above the previously laid edge of pavement should be adjusted so that when the longitudinal joint is properly compacted the pavement should be uniform in cross section and smooth riding. **[401.12]**

The Inspector should observe the location of longitudinal joints during construction. The longitudinal joints should not be located in the wheel paths of traffic. Ideally, the joints will be located between lanes. If the joints are located near the wheel paths, the Engineer should be informed immediately so that the situation can be addressed.

As the trucks arrive with the bituminous mixture, the Inspector is required to collect and sign the load tickets, check for the proper completion of the ticket, deduct excessive weight as discussed in Subsection D2.02, and record the location where the mixture is placed. The Inspector should check each load for uniformity and check the temperature of the mixtures. **[401.03]** A truckload of bituminous concrete may be rejected for the following reasons:

- (a) The material is too hot or too cold.
- (b) The material has too much or too little bitumen.
- (c) The material is not uniformly mixed.
- (d) There is excess coarse or fine aggregate in the mixture.
- (e) There is excess moisture in the mixture.
- (f) There is evidence of foreign material in the load.

It is important that the Inspector on the Project and the Inspector at the plant maintain telephone communications. This is important for placing a uniform, workable mixture on the road, and will help to keep the number of loads rejected to a minimum. The spreading operations should be checked frequently to ensure that the proper amount of mixture is incorporated in the pavement. Haul trucks should not bump the paving machine when dumping the mixture into the paver, nor should the drivers of haul trucks ride the brake while paving; the result of either of these conditions will be a rough surface. **[108.06]**

As the paver proceeds, the Contractor should pay close attention to the grade or thickness required by the Plans and should adjust the control device as necessary. By observing the surface texture behind the paving machine and checking the surface with a straightedge, a malfunction in the paver or non-uniformity of the mixture may be detected. The Inspector is

responsible to ensure prompt action on the part of the Contractor in locating and correcting any trouble that may occur.

The Contractor should regulate the speed of the paver to reflect the production speed of the bituminous concrete plant. Paving should not be done so fast that the paver has to wait for material to be delivered or so slow that trucks have to wait to load bituminous concrete into the paver. Both of these conditions are detrimental to paving operations and will result in a poor pavement surface. If either of these conditions is observed, the Inspector should notify the Contractor to adjust the paving speed to correct the problem. The paver should always maintain a continuous forward movement. **[401.05]**

The paving crew should be thoroughly familiar with the operation and adjustments of the automatic screed control. If the automatic screed control malfunctions, the Contractor must stop paving immediately and attempt to repair the screed, because the automatic screed control tends to compound its errors. If the screed cannot be easily repaired, it can be operated manually for the rest of the day, as long as the pavement meets the requirements of Section 401 of the Specifications. If the screed malfunction caused irregularities in the pavement surface, the pavement should be corrected immediately before proceeding with any further paving operations. The operation of the automatic screed control is described in Section G401 of this Manual. **[401.05]**

**E401.08 Compaction.** Compaction should be performed using the type and number of rollers and method of rolling stated in the Specifications. Rolling should not start until the Inspector has verified that the equipment is of the type and in the operating condition stated in the Specifications. **[401.06] [401.10]**

Rolling of the longitudinal joint should be accomplished immediately after paving. The first, or breakdown, rolling should be done as soon after paving as possible without cracking the mat or having the mix stick to the roller wheels. When using Superpave mixes, it is critical to have the roller as close behind the paver as possible to achieve compaction. The second, or intermediate, rolling should follow the breakdown rolling as closely as possible. Intermediate rolling should be done while the paving mix is still above 200 °F (93° C) to obtain maximum density. This temperature should only be used as a guideline. A number of environmental factors, such as air temperature and humidity, can affect the minimum temperature necessary to ensure maximum density. The final, or finish, rolling should be completed while the material is still workable enough for the removal of roller marks. **[401.10] [401.12]**

During compaction work, the roller wheels should be kept just moist enough to avoid picking up any material. Rollers should move at a slow but uniform speed with the drive wheel closest to the paver. Changes in direction should be made gradually and rollers allowed to roll or slowly brake to a complete stop before reversing. When rollers are parked on the mat, they should be parked at a forty-five degree angle with the centerline so that subsequent rolling operations will remove any depressions resulting from the parked rollers. Rollers should never be parked on hot-mix asphalt that has not been rolled at least once. If rolling causes displacement of the pavement material, the affected areas should be loosened immediately with lutes or rakes and restored to the original grade with loose materials before being re-rolled. Rollers may be loaded or unloaded and pneumatic roller tire pressures may be varied as required by the nature and depth of the mixture to be rolled. **[401.10]**

**E401.09 Troubleshooting Pavement Problems.** Imperfections with the pavement can be caused by a number of different factors, and will be manifested in many different ways. As a

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result, it can be difficult to determine the cause of a problem. Table E-2 lists several types of pavement imperfections and the causes of these imperfections. The Inspector should use this table to assist in determining how to correct problems during paving.

**Table E-2: Troubleshooting Guide for Bituminous Pavement**

Possible Causes of Imperfections in Pavement	Types of Imperfections in Pavement												
	Bleeding	Brown, Dead Appearance	Rich or Fat Slopes	Poor Surface Texture	Rough, Uneven Surface	Honeycomb or Raveling	Uneven Joints	Roller Marks	Pushing or Waves	Cracking (many fine cracks)	Cracking (large, long crack)	Rocks Broken by Roller	Tearing of Surface during Laying
Insufficient or Non-uniform Tack Coat					•				•				•
Improperly Cured Prime or Tack Coat					•				•				•
Mixture too Coarse				•	•	•	•		•			•	•
Excess Fines in Mixture				•				•	•	•			•
Insufficient Asphalt		•				•			•	•			•
Excess Asphalt	•		•					•	•				•
Improperly Proportioned Mixture	•		•	•	•	•		•	•	•		•	•
Unsatisfactory Batches in Load	•		•	•	•	•			•				•
Excess Moisture in Mixture		•							•				•
Mixture too Hot or Burned		•											•
Mixture too Cold				•	•	•	•	•				•	•
Poor Spreader Operation				•	•	•	•		•			•	•
Spreader in Poor Condition				•	•	•	•		•			•	•
Inadequate Rolling				•	•	•	•	•					•
Rolling at Wrong Time				•	•	•	•	•	•	•		•	•
Over-rolling				•						•	•	•	•
Rolling Mixture when too Hot				•	•		•	•	•	•			•
Rolling Mixture when too Cold				•	•	•	•	•				•	•
Roller Standing on Hot Pavement					•			•					
Overweight Rollers					•			•	•	•	•	•	•
Roller Vibration					•				•				
Unstable Base Course					•		•		•	•	•		•
Excessive Moisture in Subsoil										•	•		•
Excessive Prime or Tack Coat	•		•										•
Poor Handwork behind Spreader				•	•	•	•						
Excessive Hand Raking				•	•	•	•		•				
Labor Careless or Unskilled				•	•	•	•	•					
Excessive Segregation in Laying			•	•	•	•	•						•
Faulty Allowance for Compaction							•						
Operating Finishing Machine too Fast				•	•								
Mix Laid in too Thick of a Course									•				
Traffic Put on Mix while too Hot									•				

**E401.10 Surface Test.** The finished surfaces are to be tested with a 10' (3.048 m) straightedge, furnished by the Contractor, to ascertain whether the surfaces are within the tolerance indicated in the Specifications. [401.13]

**E401.11 Inspector's Checklist.** There are a number of details that the Inspector must be aware of in order to ensure that the Contractor produces a bituminous concrete pavement in conformance with the Specifications. In order to make bituminous paving go smoothly, the Inspector should:

- (a) Inspect the condition and adjustment of paving machines and rollers prior to the start of paving. [401.04] [401.05] [401.06]
- (b) Ensure that traffic control is organized and functioning properly, and that all signs are in place. [104.09] [108.05]
- (c) Calculate the required tonnage of hot-mix asphalt for the area to be paved. Use the Hot Mix Tonnage Needed for Release form in Part H.
- (d) Check the application of the tack coat and do not allow tacking of more surface than will be paved each day. Be sure the Contractor tacks adjoining surfaces, such as gutters, curbs, manholes, and other areas that are adjacent to the roadway. [401.07]
- (e) Inspect the pavement base to ensure that the required patching and pre-leveling have been completed. [401.08]
- (f) Determine that the Contractor has set the paver guidelines properly. [401.08]
- (g) Inspect the transverse joints for smoothness and appearance. [401.12]
- (h) Observe trucks dumping material into the paver hopper for any adverse affect on the paving operation.
- (i) Check the temperature of the mix occasionally.
- (j) Maintain constant observation of the mat behind the paver for signs of roughness or non-uniformity of the mixture. [401.08]
- (k) Ensure that the longitudinal joint is tight and compacted properly. [401.12]
- (l) Make frequent checks of the screed. [401.05] [401.08]
- (m) Observe the compaction operations to ensure that the best rolling sequence is used to fit conditions and that the rollers are not moving too fast. [401.10]
- (n) Coordinate compaction testing with the Materials and Research Section. [401.11]  
A sample compaction test report is in Part H.
- (o) Keep accurate records of the truckloads used each day. Coordinate the daily totals calculated on the Project site with the daily totals made by the Inspector at the plant.
- (p) Perform yield checks using the standard form in Part H.
- (q) With the Contractor, see that the Project is in good shape prior to leaving at the end of the day. Ensure that the Contractor has properly placed barricades, lights, and other required traffic control devices. All signs not required during non-working hours are to be removed or covered. [104.09] [108.05]

**E401.12 Records.** The Inspector's records should reflect a complete summary of paving operations on the Project. These records should include the load tickets and the record of loads received, with the bitumen content and the location where the load was placed. This information will be shown on the Inspector's Daily Report and submitted with the Hot Mix Yield Check

forms. The Inspector measures the area paved each day and provides this information with the total weight of the material placed, and the load tickets when any loads have been rejected. The records of the amount of material produced and the amount of material placed must agree and must be properly documented to form a basis for the pay quantities.

## **SECTION E402 – HOT-MIX BITUMINOUS CONCRETE AND COLD-LAID BITUMINOUS CONCRETE FOR TEMPORARY ROADWAY MATERIAL (TRM)**

**E402.01 General.** This work consists of furnishing and placing hot-mix bituminous concrete and cold-laid bituminous concrete as temporary roadway material (TRM).

Hot-mix bituminous concrete and cold-laid bituminous concrete are used as TRM for the maintenance and repair of the roadway, pipe and utility crossings, and similar areas. Hot-mix bituminous concrete is similar to hot-mix, hot-laid bituminous concrete, and must meet the same material requirements as hot-mix, hot-laid bituminous concrete. Cold-laid bituminous concrete is a mixture similar to hot-mix bituminous material, and may contain additives. Additives, when required, are such that they render the mixture workable so that it may be transported, stockpiled, and placed cold. There are many different combinations of materials used in cold-laid bituminous concrete mixtures, but all combinations are categorized under two general types. The first type consists of mineral aggregate mixed with bituminous material. The second type also consists of mineral aggregate and bituminous material, and includes a liquifier, which usually consists of an approved primer and additives such as hydrated lime or water. Some special kinds of cold-laid bituminous concrete are under patent and require the patent owner's approval and the payment of a royalty. [815] [823]

The use of TRM is ordinarily limited to roadway repairs and temporary filling of pipe utility trenches. Unless otherwise noted, TRM is not used for large areas such as temporary roads.

**E402.02 Paving Operations.** The road operations for cold-laid bituminous concrete are the same as for hot-mix, hot-laid bituminous concrete except for those areas described in this Subsection. Refer to Section E401 of this Manual for information on hot-mix, hot-laid bituminous concrete. After being uniformly windrowed on the paving surface in the amount necessary to give the required spread, the cold-laid bituminous concrete must be finished and compacted. No succeeding course is to be applied until the surface has been checked and approved by the Engineer. Cold-laid bituminous concrete can be placed and compacted by hand in smaller areas, usually with a weighted plate.

## **SECTION E404 – BITUMINOUS SURFACE TREATMENT**

**E404.01 General.** This work consists of constructing one or more courses of bituminous material and aggregate upon the completed and accepted foundation or existing surface.

Bituminous surface treatment is a broad term that includes several types of applications of bituminous materials with or without a cover of mineral aggregate. Bituminous surface treatments fall into one of the four categories described below.

- (a) *Prime Coat.* A prime coat consists of a low-viscosity bituminous material applied directly on the surface of a base foundation course that is to receive some type of

bituminous wearing surface. The purpose of the prime coat is to penetrate the existing surface, to coat and bond any loose mineral particles to the surface, to provide a dust-free surface for subsequent bituminous applications, and to promote adhesion between the coat and any subsequently-placed surface course.

- (b) *Seal Coat.* A seal coat consists of a bituminous material applied on an existing bituminous surface. A single, uniform application of cover aggregate is immediately (in less than a minute) placed on the bituminous material. The cover aggregate is then promptly embedded in the bituminous material by rolling. Seal coats are used to extend the service life of an existing roadway by providing some waterproof protection, slightly increasing the strength, and improving the surface texture.
- (c) *Single-Course Surface Treatment.* A single-course surface treatment is very similar to a seal coat treatment, except that the placing operation is repeated until the desired number of courses is obtained. The maximum size aggregate for each successive course is often smaller than the preceding course.
- (d) *Tack Coat.* A tack coat consists of a bituminous material applied on an existing pavement surface to ensure a thorough bond between the old and new courses. Tack coats are used primarily with the higher service level types of bituminous pavements. [401.07]

**E404.02 Inspection of Materials.** Prior to the use of any materials, they must be inspected and tested for conformance with the requirements of the Specifications. [106.02] [404.02] [404.03] [404.04]

**E404.03 Inspection, Calibration, and Adjustment of Equipment.** All equipment proposed for use must be inspected for conformance with the Specifications. All material-carrying equipment must be calibrated by the Contractor so that the quantities of material used may be determined. All equipment that is to spread or distribute material is to be adjusted by the Contractor so that the materials may be properly and uniformly placed. The inspection, calibration, and adjustment of the major parts of the equipment used and the determination of important values for the equipment are discussed in the following subsections. [105.02] [108.06]

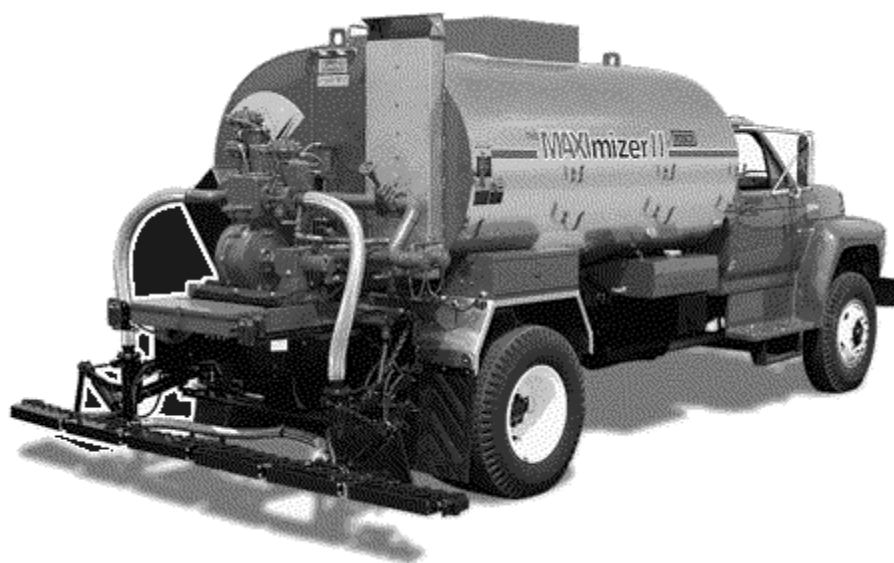
**E404.04 Bituminous Material Distributor.**

- (a) *Tank.* The tank consists of an isolated shell with flues, a thermometer, baffle or surge plates, a manhole, and an overflow pipe. The capacities of distributor tanks vary considerably. All tanks are equipped with a float-type gauge and a measuring stick for determining the amount of material in the tank. Subsection E404.10 describes construction procedures for bituminous surface treatments. [404.05 (h)]
- (b) *Heating System.* The heating system consists of one or two burners and an equal number of heating flues. Each burner emits a flame directly into a flue that transfers heat to the bituminous material. The heating system should be checked by the Inspector to ensure that it is capable of maintaining the bituminous material at the desired application temperature. When being heated, the bituminous material must be circulated. Care should be taken by the Contractor that the safe maximum heat of the material is not exceeded. [404.05 (b)]



- (c) *Circulating System.* The circulating system will be either a pump distributor or an air distributor. The pump distributor consists of a pump and lines passing through the distributor tank to the spray bar and to the hand spray. The pump is to be checked by the Inspector to ensure that it is capable of circulating the bituminous material through the tank and the spray bar. The system is to develop and maintain a constant, uniform pressure along the entire length of the spray bar so that an equal amount of material will be sprayed from each nozzle without atomizing the bituminous material or emitting a distorted fan. The control for the valve system, which controls the discharge of bituminous material from the nozzles, should be inspected and adjusted if necessary. There should be no slack in the linkage from the control to the valve system. It is important to ensure that all of the nozzles respond immediately to the control. **[404.05 (e)]**
- (d) *Spray Bar.* To ensure the proper working condition of the spray bar, the inspections outlined below are to be made by the Contractor and observed and recorded by the Inspector. **[404.05 (g)]**
  - (1) *Nozzles.* The nozzles should be removed from the spray bar, cleaned, and examined for size, wear, and damage to the edges of the nozzle openings. Uniform distribution of the bituminous material depends on the nozzles being in good condition and being of the proper size. All nozzles are to be of the same type. Usually the smallest size nozzle available for a distributor will provide the most uniform distribution. The nozzles should be set so that the slots make the angle with the spray bar as recommended by the manufacturer of the equipment.
  - (2) *Spray Bar Height.* The height of the spray bar should be set so that the exact number of laps of bituminous material desired will be obtained. The height for a double lap may be determined by closing every other nozzle, operating the distributor at the proper pump speed or pressure, and raising or lowering the spray bar by not more than one-half of an inch (13 mm) at a time until it is determined by visual observation that exactly one single lap of a double lap of material will be applied. For a triple lap, two of every three nozzles should be closed, and then the above procedure should be followed.
  - (3) *Springs.* The distributor truck should be equipped with springs that are strong enough so that different truck weights will not result in a difference in the height of the spray bar. Weak springs would cause a full distributor tank to be closer to the ground. As the tank discharged material, the truck would rise away from the ground. This would significantly affect the uniformity of the distribution of the bituminous material. If the uniformity of the distribution is affected, recommendations may include installing stronger truck springs or connecting the frame of the distributor to the axle when the tank is fully loaded. In any instance, the work should not be allowed to proceed until corrective action is taken by the Contractor.
  - (4) *Spread.* To ensure uniform distribution, the transverse spread and the longitudinal spread should be monitored for any irregularities that would affect the consistency of the coating.

Figure E-11 shows a typical bituminous material distributor.

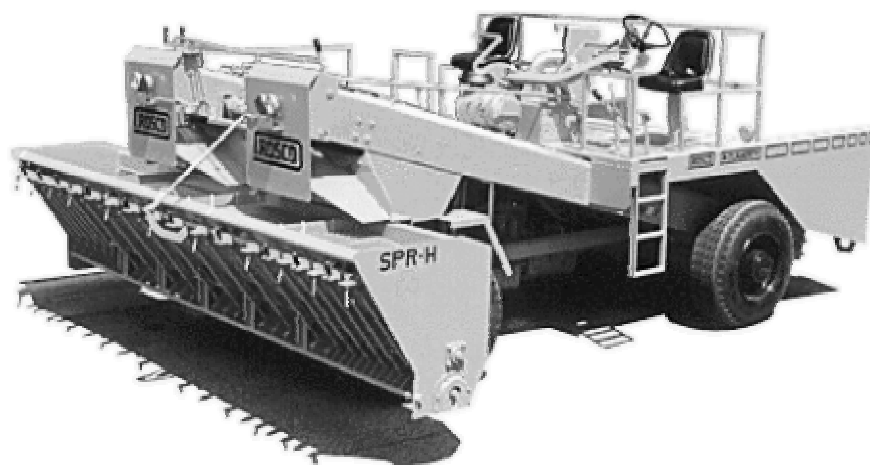


**Figure E-11: Bituminous Material Distributor**

**E404.05 Aggregate Spreader.** Aggregate spreaders are of three general types: tail gate, mechanical, and self-propelled. Of these types, the self-propelled spreader is the most satisfactory. It affords close control of traveling speed, has the ability to apply the cover aggregate in a continuous and more uniform manner, and can stay close to the distributor. [404.06]

- (a) *Calibration and Adjustments.* The aggregate spreader should be calibrated and adjusted in accordance with the manufacturer's recommendations and operating manual.
- (b) *Spread.* The transverse spread and the longitudinal spread should be checked to make certain that uniform distribution will be obtained.
- (c) *Operating Speed.* The operating speed should always be such to prevent the spreader from causing it to lope or undulate.
- (d) *Connecting Hitch.* For mechanical and tailgate spreaders, the hitch used to connect the spreader to the aggregate truck should be inspected to be certain that it will afford a positive connection.

Figure E-12 shows a typical self-propelled aggregate spreader.



**Figure E-12: Self-Propelled Aggregate Spreader**

**E404.06 Aggregate Trucks.** Each truck used in hauling the cover aggregate should be assigned an equipment number after it has been inspected for compliance with the Specifications. [105.02]

- (a) *Calibration.* Cover aggregate is measured by weight. Section D2.00 provides information for control of truck weights and record keeping.
- (b) *Connecting Hitch.* For mechanical and tailgate spreaders, the hitch used to connect the spreader to the aggregate truck should be inspected to be certain that it will afford a positive connection.

**E404.07 Truck Scales.** Requirements for scales are included in Subsection 109.01 of the Specifications. [109.01]

**E404.08 Rollers.** At least two rollers, one three-wheel steel-wheel roller and one pneumatic-tire roller, must be used when placing bituminous surface treatment. The pneumatic-tire roller should be inspected to determine that it can be loaded to the desired weight and that the tires are inflated to the air pressures necessary to provide the desired ground contact. Refer to Subsection 404.08 of the Specifications for the requirements for design, weight, and tire pressure requirements for pneumatic-tire rollers, and for the requirements for three-wheeled steel-wheel rollers. Refer to Division G302 for more information on the operation of these types of equipment.

**E404.09 Power Broom.** Normally, when self-propelled aggregate spreaders are used, power brooms are used for cleaning the existing surface in preparation for construction and for removing excess aggregate from the new surface after the bituminous material has hardened. [404.07]

**E404.10 Construction Operations.** Construction operations are important when performing penetration surface work. Even the most precise design will be of no value if the construction operations are not properly conducted.

- (a) *Preparation of the Existing Surface.* During new construction, the grade must be carefully checked prior to surfacing. The riding surface of the new penetration

surface can be no better than the surface on which it is placed. For additional information on surface preparation, refer to Subsection E300.04.

- (b) *Repairing Defects.* Normally, a new base course will not require repair to the surface since the base course is constructed to the specified tolerance. For existing bituminous surfaces, it is generally necessary to make repairs to surface defects. The most common surface defects are raveling, cracks (such as transverse, longitudinal, alligator, slippage, and shrinkage), broken edges, potholes, corrugation, depressions, bumps, foreign material adhered to the surface, absorbent areas, and flushed or bleeding areas. Repairs to these defects should be accomplished well in advance of the construction operations.
- (c) *Cleaning the Surface.* The existing surface must be cleaned just prior to applying the bituminous material. All foreign materials, such as paper and mud, should be removed and the entire surface carefully broomed to remove dirt and dust.

**E404.11 Traffic Control.** Effective traffic control is essential to the construction of a penetration surface. Traffic must be controlled to allow for the orderly movement of traffic, to avoid interruption and damage to the work, to protect construction personnel, and to maintain a safe flow of traffic around the hazards created by the operation of the construction equipment. Traffic control is best accomplished by the use of a combination of barricades, warning signs, detours, and flaggers. **[104.09]**

**E404.12 Weather Limitations.** An important factor for consideration when constructing penetration surfaces is the weather. Construction operations should not proceed when the existing surface is frozen or wet, during foggy conditions, when it is raining or threatening to rain, or when the air temperature is below 50 °F (10 °C). **[404.09]**

**E404.13 Alignment.** All applications of bituminous materials are to be made to the width and alignment required by the Plans. As the path of the distributor follows the guide, the bituminous material will be applied to the correct width and alignment.

The Inspector must measure the width before and during the operations to ensure conformance with the Plans.

**E404.14 Application of Bituminous Material.** Immediately prior to the application of the bituminous material, the Inspector should measure and record the quantity of material in the distributor tank. The distributor should be parked off the roadway on a level surface for this operation to ensure a correct reading. The bituminous material in the tank should also be checked to ensure that it is at the desired application temperature. If necessary, the material should be heated to the required temperature prior to applying. After completion of the application of the material, the quantity remaining in the distributor tank should be measured and recorded. Refer to Subsection E304.10 for detailed measurement instructions. From these measurements and the measurements of the area covered, the Inspector should calculate the rate of application, or yield. Other methods used to check the yield may be used only if approved by the Engineer. **[109.01]**

The Contractor should provide close control over the application so that the material is applied uniformly. Proper inspection and adjustment of the distributor should provide a uniform application unless one or more of the nozzles become clogged. To obtain the desired uniform

rate of distribution in the longitudinal direction, the circulating pump and the distributor must be operated at the proper speed. The length of spread for each distributor load of material should be determined and marked on the road as an aid to obtaining the desired rate of application.

**[108.06] [404.11]**

Because bituminous materials cool rapidly, the distribution of the material should be coordinated with the spreading of the cover aggregate if cover aggregate is shown on the Plans. The time lapse between the distribution of the bituminous material and the application of the cover aggregate should be kept to an absolute minimum to obtain greater wetting action and better seating of the aggregate. **[404.12]**

The transverse joints on seal coats and on surface treatments should be carefully made so that they will not be rough and unsightly. This may be accomplished by starting and stopping each application of bituminous material and cover aggregate on building paper. Each successive application should overlap the end of the preceding application by 1" (25 mm) to avoid a gap in the surface. **[404.11]**

The longitudinal joints for seal coats and surface treatments that are not placed to the full width of the roadway in a single pass should also be carefully controlled. It is not practical to use building paper on these joints, so it is more desirable to have a slight build-up due to overlapping the adjacent passes than to have a gap in the surface.

**E404.15 Application of Cover Aggregate.** A minimal amount of time should be allowed to elapse between the application of bituminous material and the spreading of coarse aggregate. Ideally, the Contractor should begin to spread the aggregate less than a minute after the bituminous material is applied. A properly adjusted aggregate spreader that is operated at the proper constant rate of speed will provide the desired uniform rate of application and preclude the spreading of cover aggregate by hand. **[404.06] [404.12]**

The Contractor should ensure that the aggregate being spread is clean and is not spread in too thick a layer. Excess aggregate will not adhere to the bituminous material and will ravel off, creating a loose surface.

**E404.16 Rolling with Pneumatic Tire Rollers.** Rolling should immediately follow the aggregate spreading in order to embed the aggregate while the bituminous material is still soft and tacky. The rolling procedure should be as outlined in the Specifications. **[404.13]** Normally, one pass with the roller is adequate on all courses of aggregate; however, the Contractor is required to roll the area as often as necessary to ensure that the coarse aggregate is firmly embedded in the bituminous material. **[404.13]**

## DIVISION E500 – RIGID PAVEMENT

### SECTION E501 – PORTLAND CEMENT CONCRETE PAVEMENT

**E501.01 General.** This work consists of constructing a jointed portland cement concrete pavement on a prepared base using either fixed forms or slip forms. Slip-form paving may be used when requested by the Contractor and approved by the Engineer.

The construction of concrete pavement is a highly mechanized operation that requires a working knowledge of many types of equipment in addition to the knowledge of inspection procedures for a large quantity of material. Inspectors assigned to this work should become thoroughly familiar with the Specifications (both the Standard Specifications and the Special Provisions), construction details, and the order of work. Prior to the start of paving operations, a pre-pour meeting should be arranged between the Contractor's supervisory personnel, suppliers, Materials and Research representatives, Inspectors, and any other Department personnel that the Resident Engineer/Project Supervisor deems necessary. For slip-form paving operations, the Specifications require the meeting seven days prior to beginning paving. The purpose of this meeting is to identify the sources of material, procedures for handling the material, methods of operation, equipment to be used, and the Specification requirements. The construction and testing methods are to be those prescribed by the Plans and Specifications. A synopsis of the discussion is to be written by the Inspector, and copies are to be forwarded to the Engineer, Project file, other inspectors, and the Contractor.

**E501.02 Paving Equipment.** A variety of equipment is used in concrete paving operations. A truck will transport the concrete from the batch plant to the paving equipment. The paving equipment will then spread the concrete, strike it off to the proper thickness, vibrate the concrete to consolidate it, and screed the surface to get it smooth and even. These operations may be conducted by a single paving machine or different machines that perform different tasks. The Inspector should be thoroughly familiar with the operations of the different types of paving equipment, and with the requirements of the Specifications regarding this equipment. **[501.05]**

As mentioned above, slip-form paving may be used only when approved by the Engineer. In all other cases, fixed-form paving must be used. Slip-form paving equipment and details are discussed in Section G501 and Subsection E501.17, respectively.

The following list provides some general information on the equipment used in fixed-form paving. This information can also serve as a partial checklist for the Inspector when inspecting fixed-form paving equipment before and during use.

- (a) *Mechanical Spreader:* The elevations of the bottom of the distributing device and strike-off, whether screw or plow type, are adjustable. When checking the spreader, the strike-off should be set level with the top of the forms, at which time the gauges, visible to the operator, should read zero. The strike-off should then be adjusted for proper thickness, and the distributing device should be adjusted so that some concrete will be carried in front of the strike-off. **[501.05]**
- (b) *Transverse Finishing Machine:* The transverse finishing machine has two transverse screeds. The screed wearing plates that ride on the forms should be checked for signs of wear. When two finishing machines are used, both screeds on the rear machine should have little or no tilt. **[501.05]**

The Contractor may use the following method to adjust the screeds:

- (1) Center the screeds and lift them off the forms.

- (2) Stretch fine wires taut between the forms at the front and back of each screed.
  - (3) Place blocks of uniform thickness on top of the wires at each form.
  - (4) Lower the screeds.
  - (5) Place the proper crown in the screed by measuring between the taut wire and the face of the screed, and adjust the hanger bolts accordingly.
  - (6) Tilt the front screed so that the front edge is slightly higher. Set the rear screed flat or with no more than a 1/16" (1.5 mm) tilt.
- (c) *Longitudinal Float Finisher:* A float finisher has a greater effect on the finished pavement than any other machine since it corrects irregularities left by preceding operations. The adjustment of this machine is very important. The Contractor may use the following method to adjust the float finisher:
- (1) The float should be straightedged to verify it is not warped.
  - (2) Inspect the height of the transverse tracks at the front and rear of the machine that carry the float assembly to ensure that all four ends are the same distance above the plane of the bottom of the wheels.
  - (3) Place taut wires across the top of the forms and adjust the tracks to conform to the proper cross section of the finished roadway.
  - (4) Stretch two wires across the top of the forms, separated by a distance equal to the length of the float. When the float is lowered, all four corners of the float should be the same distance from the wire equal to the ordinate of the desired cross section.
- During the above procedures, the float should be loaded with approximately the same weight that it will carry during operation, including the weight of the operator. Scrapers should be in good condition and kept in tight contact with the flanged wheels or forms at all times. The Inspector should not allow adjustments of the float position by the operator during paving operations to compensate for either surplus or insufficient concrete. **[501.05]**
- (d) *Vibrators and Tampers:* Hand vibrators for this type of work are required to have a frequency of at least 3,500 vibrations per minute. Vibrators that are a part of the finishing equipment usually have a frequency of at least 5,000 vibrations per minute. Tampers, if permitted or required, are to comply with the Specifications. The vibrations must be checked with a tachometer or other approved equipment by the Inspector prior to the start of work and at least once a day during the paving operations. Automatic vibrators should be adjusted to avoid displacement of joint reinforcements and tie-bars by the vibrators. Additional information may be found in the Specifications. **[501.05] [501.08]**
- (e) *Hand Tools and Auxiliary Equipment:* Prior to the start of paving operations, all hand tools and auxiliary finishing equipment should be inspected to ensure they are in satisfactory condition and are in conformance with the Specifications.

**E501.03 Preparation of Grade.** Prior to the start of paving operations, the Inspector is to ensure that the foundation is constructed to the approximate typical section. The Inspector should also ensure that the grade is of the proper density, including the form line for fixed-form paving or the

paver's track path for slip-form paving. It is recommended that the foundation be constructed slightly higher than the fine grade elevation.

**E501.04 Conditioning of Foundation or Base Course.** Before the forms for fixed-form paving or the stringline for slip-form paving are set, the fine grade should be cut with an approved foundation/grade machine. The quantity removed during fine grading operations should be moved ahead. If the base is low, the area should be raked, material should be added, and the base should be wetted and re-compacted. After final shaping of the foundation, it should be compacted as required in Division 300 or 400 of the Specifications, depending on the base course material. Immediately ahead of the paving operations, the foundation grade should be checked in accordance with the Specifications. In addition, periodic checking should be accomplished by measuring down to the foundation from a taut string or wire stretched across the forms. These measurements should be recorded. The foundation should be uniformly moist, but not muddy, at the time the concrete is placed. **[501.03]**



**Figure E-11: Trimming the Base Course for Concrete Paving**

**E501.05 Setting Forms for Fixed-Form Paving.** Forms should be inspected to ensure that they meet the dimension requirements stated in the Specifications. The forms should be clean, oiled, and straight. The face of the forms should be perpendicular to the base. The flanges should not be bent, and the locking devices should be in proper working order. The foundation for the forms is to be cut true to grade, usually from a reference stringline. When the forms are set, they are to be firmly supported throughout their length. The pins are to be long enough to avoid measurable movements under loading by equipment, and should be locked in the stake holes. Locking



devices must be properly fastened. The width between the forms is to be correct. The forms should be the proper distance from the centerline and at the correct elevation with a smooth grade line. After the forms are set, the top forms should be sighted to detect variances from the grade or alignment shown on the Plans. The Contractor should make any adjustments necessary before paving begins. **[501.06]**

#### **E501.06 Limitations to Mixing and Paving.**

- (a) *Cold Weather Concreting:* Mixing and placing concrete may begin when the ambient temperature reaches 35 °F (2 °C) and is expected to rise. The temperature of the mixed concrete is to be between 50 and 90 °F (10 and 32 °C) at the time of placement. When it is necessary to heat mixing water and/or aggregates, they shall be heated to not less than 70 °F (21 °C) or more than 150 °F (65 °C) in such a manner that the mass is uniformly heated. Concrete that is too hot will result in overheated areas in the concrete, a condition that must be avoided.

Concrete is never to be placed on frozen foundations, and frozen aggregate is never to be used in the concrete. If the nighttime temperature drops below 32 °F (0 °C) for more than a few hours, it may be necessary to cover the prepared subgrade with insulating blankets. This is particularly important in shaded areas that will not be warmed by direct sunlight. Concrete placed during cold weather should be produced, delivered, and finished in a manner to provide for a minimum loss of heat. Finished concrete is to be cured and protected in a manner that will protect it from freezing until the desired strength is attained. High early admixtures may be used to hasten the initial set only when authorized by the Materials and Research Section. **[501.04]**

- (b) *Hot Weather Concreting:* When hot, dry, and windy conditions prevail, it may become necessary to take precautions to prevent rapid surface drying, rapid temperature changes, and undesirable high temperatures in the concrete during the early stages of hardening. These conditions may remove moisture from the pavement surface faster than the moisture can be replaced by normal bleeding, and may cause plastic shrinkage cracks to form.

There are a number of actions the Contractor can take to successfully place concrete in hot weather. It may be desirable to cool the mixing water and aggregate stockpiles to lower the temperature of the concrete. The forms may be cooled by sprinkling them with water or by dragging a piece of wet burlap over them immediately before concrete placement. The application or placement of curing materials immediately upon completion of finishing becomes extremely important, and under some conditions, it may be necessary to use wet burlap or cotton mats for the first 24 hours after placement. The wet burlap or mats can be used for the remaining curing period, or can be removed and replaced with other curing materials. Concrete placement can also be done at night when the temperature is cooler. The recommended maximum temperature in plastic concrete is 90 °F (32 °C). **[501.04]**

- (c) *Protection in Case of Rain:* Prior to the start of paving operations, the Inspector should ensure that the Contractor has sufficient material on hand, such as burlap, polyethylene sheeting, or other approved material, to properly protect the pavement surface in case of rain. Sudden showers that occur during placement

operations or immediately after finishing operations require the exposed surface of the fresh concrete to be covered to prevent the washing of cement from the surface. Mixing and placing of concrete should cease immediately in case of rain. If it only rains for a short period of time, the protective covering may be removed and finishing may be completed. If the rainfall continues, finishing may be accomplished by rolling back a few yards (meters) of the protective covering at a time and replacing the covering immediately after finishing is complete. The pavement surface is to be inspected as soon as possible to determine the extent of damage from rainfall. The Contractor is to be advised immediately of any corrective action or removal that may be required. [501.14]

**E501.07 Placing Concrete.** Formed pavement concrete is to be placed on the foundation in such a manner as to prevent segregation and minimize redistribution. Concrete dumped in piles causes non-uniform consolidation and additional strain on the forms and spreader. This type of placement generally results in increased finishing work to achieve a good riding surface. Do not allow vibrators to be used to move concrete or lower large piles. Vibrators are only to be used to consolidate concrete around rebar, forms, or dowels once concrete is in place. The Contractor should be careful to avoid displacement when placing concrete around areas such as joint assemblies, dowels, and expansion joints. [501.07]

The Inspector should coordinate with the Materials and Research Section to ensure a Section representative is available to perform concrete tests and take samples according to the Contractor's schedule for placing concrete. When the tests have been completed, the Inspector should ensure that the recorded test results, along with the PCC ticket, are made a part of the Project's permanent records. Sample PCC tickets are in Part H. Typically, entrained air and slump test results will be available immediately in the field. Two compressive tests each are performed at 7 and 28 days. If early strength tests are needed, the Materials and Research Section must be informed so that additional cylinders can be made. The Inspector should obtain these test results as soon as they are available and review them with the Contractor. Again, the Inspector must ensure that the compressive test results become a part of the Project's permanent records. A sample Concrete Compressive Strength Report is in Part H.

When spreading concrete by hand, a shovel should be used. Avoid throwing concrete with the shovel; instead, drop the concrete off the shovel by turning the handle. Rakes and similar tools are not to be used for this work because they affect the homogeneity of the mix.

**E501.08 Joints.**

- (a) *Load Transfer Devices:* When load transfer devices are required for transverse joints, they must be laid out and marked so that the exact centerline of the assembly may be re-established after they are covered with concrete. The concrete will be saw cut to create a contraction joint at this centerline.



**Figure E-14: Centerline of Dowel Bars Marked before Paving**

Generally, the assemblies are held in the correct position by the use of metal stakes or pins that are driven into the base course. The dowels are fixed (welded) on one side of the support basket, while the other side of the dowel is free moving and carefully coated with an approved lubricant. Load transfer devices may come to the Project site pre-lubricated. The correct positioning of this assembly is important. Inspections are to be made for each unit immediately prior to the placement of concrete. [501.16]

- (b) *Tie Bars*: Tie bars installed across the centerline must be parallel to the surface and at right angles to the centerline. Unless an approved mechanical device operating immediately behind the spreader, or behind the strike-off for slip-form paving, is used for the installation, the tie bars must be installed before placing the concrete and must be held securely in position. [501.16]

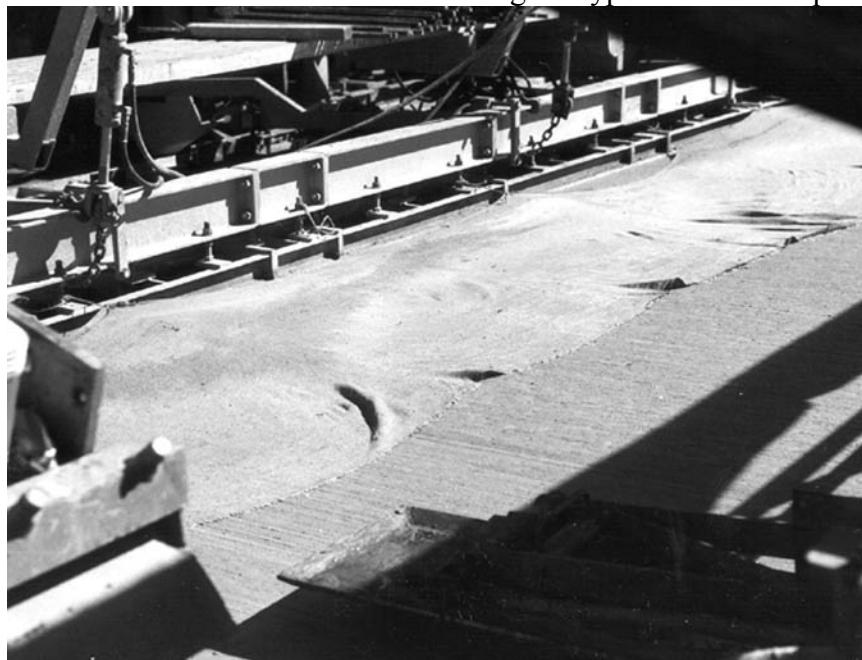


**Figure E-15: Mechanical Tie Bar Placement**

**E501.09 Final Strike-off, Consolidation, and Finishing.** Immediately after spreading, the concrete should be screeded and consolidated with an approved finishing machine and vibrators, or other approved equipment.

The finishing machine should have at least two oscillating-type transverse screeds in proper adjustment. The purpose of this machine is to assist in consolidating the concrete and to leave the surface with a uniform texture and at a reasonably correct elevation and cross section for final finishing. When the spreader and the finishing machine are properly adjusted, there should be a uniform roll of concrete in front of each screed. The roll in front of the first screed should be larger than the roll in front of the back screed. The roll in front of the back screed should be sufficient to provide a uniform surface while leaving enough material for final finishing. If an excess of concrete is being carried, it will tend to lift the screeds off the forms. In addition, there will be surging behind the screed, resulting in overloading the equipment that follows it. As the work progresses, the tilt and speed of the screeds may need to be adjusted to compact the particular mix being used, to eliminate tearing, and to control the amount of surge. With stiff, harsh mixes, the screed oscillating speed should normally be rapid, with a long stroke and slow forward speed. With more fluid mixes, the screed action should be decreased in both frequency and length of strokes, and the forward speed should be increased. The vibration frequency will be determined by field conditions. Excess screeding should be avoided since it tends to result in undesirable quantities of low strength mortar on the surface. The finishing machine wheels and the top of the forms should be kept clean at all times. An approved hand-type vibrator should be used along the forms. Equipment other than vibrators used for consolidation must be approved by the Engineer and produce satisfactory results.

The drag finish is accomplished with a seamless strip of damp burlap or cotton fabric dragged longitudinally along the full width of the pavement. The drag is to be maintained clean and free of encrusted mortar, and should produce a surface uniform in appearance. The applicable Specifications are to be followed concerning the type of surface required.



**Figure E-16: Drag Finishing with Burlap Attached to Paver**

After consolidating and screeding, the concrete is to be floated to remove irregularities left by previous operations and shrinkage. This operation may be done with a longitudinal or transverse float, properly adjusted as described in Subsection E501.02. The time when floating can be done will depend on the field conditions. It is desirable that initial settlement of the concrete be completed before floating begins. If the concrete has not been thoroughly compacted and is in the early stages of shrinkage when the float passes, the final surface may eventually be rough. Floating should be held to a minimum during the period of greatest bleeding since working the surface in the presence of excess water leaches out a portion of the cement and produces low strength surface mortar. The longitudinal float should be operated so that the entire surface area is covered at least twice. This is accomplished by overlapping the previous transverse pass by one half the length of the float. Excessive floating should be avoided. When operating properly, the longitudinal float should carry a small roll of concrete along all but approximately the rear 2' (600 mm) of its length. **[501.05] [501.08]**

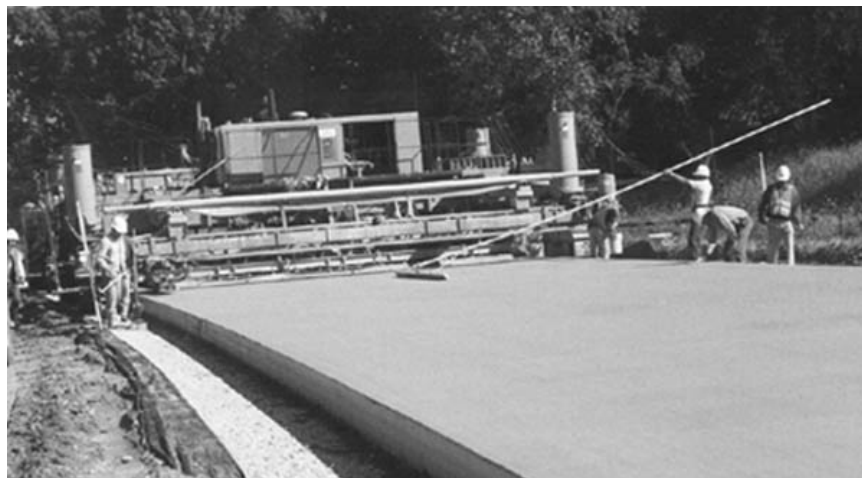
If excessive cutting down of excess concrete or filling in low spots in the concrete is required, all paving equipment should be checked and necessary adjustments made to eliminate the high and low spots.

When the transverse float is used, the time of operation must be adjusted to the field conditions. This will be similar to the requirements for using a longitudinal float. The screeds working ahead of the transverse float should carry a uniform roll of concrete so that the transverse float will leave a smooth, uniform surface free of screed marks and with a minimum of surging. **[501.08]**

A continuous operation at a uniform speed is necessary for obtaining the most desirable finished surface regardless of the type of float used. **[501.09]**

Generally, adding water to the surface to facilitate finishing is not permitted; however, if water must be used, it should be used sparingly and applied only as a fog spray using approved spray equipment.

When hand methods of finishing are permitted, the surface should be checked with a hand-operated longitudinal straightedge 10' (3.048 m) in length. It should be straight and rigid enough to prevent flexing or warping. It is worked from one side of the pavement to the other. Each pass should overlap the preceding one by not less than one-half the length of the straightedge. When it is necessary to smooth or fill in open-textured areas in the pavement surface after the straightedge operation, it is allowable to use an approved long-handle bull float. The float is operated with a sawing motion while being held parallel to the centerline. The Inspector should caution the Contractor that extreme care is to be used to avoid distorting the surface, and that this type of operation should be limited to small areas only. If the finishing machine is properly operating, the need for the use of a bull float should be minimal. **[501.09]**



**Figure E-17: Hand-floating Concrete Pavement**

Edging of the pavement surface adjacent to the forms and joints is to be done with edging tools that are in conformance with the Specifications. The concrete should have set enough to permit the edges to hold the desired shape after edging is finished. Care should be taken to ensure that the leg between the concrete and the form or joint is held vertical. Marks left on the pavement surface during edging work are to be removed by using a clean, wet paintbrush or a small piece of damp burlap.

For slip-form paving, the Inspector must check for edge slump using a straightedge placed transversely across the pavement.



**Figure E-18: Using Burlap to Remove Marks from Edge Finishing**

After edging and floating have been completed and excess moisture has evaporated from the surface, the Contractor should texture the plastic concrete. Texturing should be done transversely using a mechanical texturing machine consisting of a wire comb guided either electronically or by a stringline. The texture should be produced by dragging the wire comb across the concrete in a continuous motion without dragging any mortar from the concrete surface. The Inspector must check the texturing operations to ensure proper depth and spacing

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are achieved. If the concrete begins to flow back into the grooves being formed, texturing work should be stopped until the concrete is more plastic and will not flow into the grooves. [501.09]

**E501.10 Curing.** After finishing operations have been completed and as soon as surface marring will not occur, but prior to the surface losing its sheen, or surface moisture, the entire width of the pavement should be cured. Timing of the application of curing material is extremely important and must be accomplished prior to the surface drying to avoid shrinkage cracks. Various methods of curing are used, such as liquid membrane compounds, polyethylene sheeting, and waterproof paper.

- (a) *Liquid Membrane Compounds.* Liquid membrane compounds are to be applied uniformly with automatic spraying equipment at the specified minimum rate. Frequent checks of the quantity used in relation to the surface should be made and recorded to ensure the proper rate of application. Should the curing agent be damaged by rain or other cause, the damaged membrane is to be immediately repaired by adding an additional application. [501.11]



**Figure E-19: Curing Machine**

- (b) *Waterproof Paper and Polyethylene Sheeting.* Waterproof paper and polyethylene sheeting are to cover the entire concrete surface, and should be weighted to avoid displacement. If the covering does not create an accumulation of water under it, the covering is not sealed sufficiently tight and a new method is to be used. The covering is to display no movement on windy days, and there should be no evidence of moisture leaking through the cover. [501.12] [501.13]

**E501.11 Sawing Concrete Joints.** The Contractor is required to saw all transverse and longitudinal joints unless otherwise specified or directed. The Contractor should have sufficient saws and blades on hand to perform sawing operations at the proper time. Equipment for night sawing is required to be available. The time required to begin sawing varies depending on weather and atmospheric conditions. Timing of sawing is critical to prevent “late saw” cracking. Slight raveling is not objectionable, and is generally an indication that sawing is being done at the proper time. Joints must be sawed over the exact center of the load transfer devices and

perpendicular to the surface. When a crack occurs ahead of a saw cut, sawing on the joint should be stopped immediately and the saw moved ahead several joints. A joint should be sawed at this new location, and then the intervening joints should be cut. Measurements of the depth and width of sawed joints should be made periodically by the Inspector to ensure compliance with the Contract requirements. The measurements should be recorded as part of the permanent record. [501.16]

**E501.12 Surface Test.** As soon as possible after the concrete has set, the surface should be checked with either a rolling straightedge, straightedge, or California-type profilograph. [501.17] The California-type profilograph is to be used unless otherwise stated in the Contract. The inspection of the pavement is to be performed by, or supervised by, the Inspector. Should deviations be found to exist in the pavement in excess of the tolerance, the Inspector should review the deviations with the Contractor to determine the cause and consider making changes to the paving operations to minimize deviations. The paving operation is not to be allowed to continue if smoothness of the surface is not being accomplished within the specified tolerance.

All profilograph results are to be documented, with copies forwarded to the Materials and Research Section. All irregularities varying more than the requirements in the Specifications are to be corrected to the satisfaction of the Engineer. [501.17]

**E501.13 Removing Forms after Fixed-Form Paving.** Knowing when to remove the side forms requires good judgment, as weather and temperature affect this type of operation. Unless otherwise permitted, forms are not to be removed from freshly placed concrete until it has set for a least 12 hours. In all instances, the concrete should be hardened to the extent that spalling or other damage will not occur. Immediately upon the removal of the forms, all honeycomb is to be patched, and the pavement edges are to be cured using an approved method. [501.06] [501.10]

**E501.14 Sealing Joints.** Transverse joints must be filled with an approved backer rod prior to any vehicular traffic using the pavement. Sawed or formed joints are to be clean and surface dry at the time of sealing. The sealing of joints is to be done after all construction traffic is finished using the pavement and prior to opening the pavement to the public. If heated joint sealer material is to be used, the material should be stirred to avoid localized overheating, and the temperature should be continually checked to ensure compliance with the manufacturer's recommended temperature. The Contractor is responsible for ensuring that the pouring of the joints is accomplished neatly and in such a manner that the material will not be spilled on the exposed surface of the concrete. If the Work is not being accomplished in a satisfactory manner, the Work should be stopped until the Contractor can correct the problem. [501.18]

**E501.15 Protection of Pavement.** The edges and the surface of the pavement should be protected against any damage by the public or the Contractor's forces and equipment until it is accepted by the Engineer.

**E501.16 Opening to Traffic.** The completed pavement is not to be opened to traffic, including construction vehicles, until the pavement has attained the specified strength. If testing is not conducted, the pavement is not to be opened to traffic until ten days after the concrete is placed, or as directed by the Engineer. Prior to opening any pavement to traffic, the pavement is to be



clean, properly signed, marked, and cleared of all obstructions to make it safe for the traveling public.

### **E501.17 Slip-Form Paving.**

- (a) *Track Path:* The track path for slip-form pavers is normally prepared in the same general manner as the subgrade for forms. The track path must be graded, checked, and maintained in a smooth compacted condition until the pavement is constructed. Any irregularities in the track path will be reflected in the finished surface. When a stringline is used, it should be supported and tensioned to prevent any measurable sag. Immediately prior to paving, a final inspection should be made to eliminate any irregularities in the track path or stringlines.
- (b) *Placing Concrete:* When using slip-form equipment, the uniform distribution of batches is as important as it is for fixed-form paving. To distribute the correct amount of concrete for the full paving width to the main screed, pavers of this type are normally equipped with an initial strike-off blade provided with front and rear power travel that is independent of the forward travel of the paver. Because of the relatively large screed area and the physical limitations due to the weight of the machine, the importance of using concrete of proper consistency and uniform distribution is extremely critical. Piles of dry concrete will cause the paver to float, or lift above the true grade, and will result in a high area or bump. Consolidation of concrete in slip-form paving is accomplished by means of vibrators working within the mass of concrete.
- (c) *Strike-off:* Spreading is normally accomplished by the strike-off blade. The top surface of the pavement is then shaped. A preliminary finish is placed on the concrete through the action of a primary screed that usually is rigidly attached to the main frame of the slip-form paver, or by the use of an oscillating belt.
- (d) *Final Finish:* A slip-form paver produces a final finish by means of a secondary ironing screed followed by an oscillating belt and a “V” shaped, free-floating smoothing float. In lieu of this equipment, tamping bars followed by an extrusion plate and a transverse reciprocating belt are used. The sliding forms attached to the paver must be rigidly held together laterally to prevent spreading. They should be of sufficient length so that no appreciable slumping will occur and any necessary hand finishing can be accomplished while the concrete is still within the forms. Checking and texturing of the surface are performed in the same manner as required for fixed-form paving. Curing, sawing, and joint sealing are also performed in the same manner as required for fixed-form paving.

**E501.18 Tolerances in Pavement Thickness.** Prior to final acceptance, the pavement will be core drilled by the Materials and Research Section. The purpose of the core drilling is to ensure the minimum required pavement thickness was obtained and establish an adjusted unit price for the pavement based on the pavement thickness. Samples of Core Drill Reports are in Part H. If pavement thickness is not within the allowable tolerance, deductions for deficient pavement thickness should be made as specified in the Contract. The deduction penalty will be entered as a separate item on the subsequent progress estimate due the Contractor and not as a quantity reduction of the pavement. **[501.20]**

**E501.19 Measurement and Payment.** Refer to Subsections 501.20, 501.39, and 501.40 of the Specifications for detailed methods for measurement, payment, and payment adjustments related to pavement thickness and smoothness.

**E501.20 Records.** The Inspector is required to maintain current records and reports. All the test reports should be dated and signed by the person making the tests. An orderly record should be kept of all specific checks or tests made to determine compliance with the Specifications. The diary should be a concise record of pertinent daily events and observations. All entries are to be dated and identified by the signature of the writer. This record should include:

- (a) All special instructions to the Contractor
- (b) Unusual actions taken by the Inspector
- (c) Daily time for starting and ending operations
- (d) Extent of the progress by stations
- (e) Lost time due to breakdown or other reasons
- (f) Contractor's forces assigned daily by skill
- (g) Weather and temperature conditions
- (h) Any actions or events affecting the progress or quality of the work
- (i) Any unusual or adverse traffic problems.

## **SECTION E503 – PATCHING PORTLAND CEMENT CONCRETE PAVEMENT**

**E503.01 General.** The Construction sequence for patching Portland cement pavement shall be the following:

- 1) Saw-cut lines should be correctly aligned.
- 2) Use lift-out technique to remove existing pavement.
- 3) Place dowel bar holes and align the dowels.
- 4) Grout.
- 5) Place concrete (cold joints).
- 6) Consolidation.
- 7) Cure concrete.
- 8) Cover with insulating blanket.
- 9) Apply sealant.

## **DIVISION E600 – MAJOR STRUCTURES**

### **SECTION E600 – GENERAL STRUCTURES INFORMATION**

**E600.01 General.** Structures are defined in the Specifications as bridges, culverts, storm sewer appurtenances, slope and retaining walls, sign support structures, and other similar items. Storm sewer appurtenances include the reinforced concrete pipe used in storm sewers as well as the headwalls or flared end sections installed on sewer pipes. Culverts may take a number of different forms, from structures similar to normal bridge construction to box culverts and other pipe culverts. The components that make up structures, such as concrete, timber, and reinforcing steel will be discussed individually in this Division.

**E600.02 Preliminary Considerations.** The Inspector must perform a number of activities before any structural work is started. These activities include verifying survey information, checking for utilities on the Project site, and material approval.

The location survey for structures is critical. The construction centerline and benchmarks for elevation control are placed by the survey crew. In some instances, the crew may also stake out the abutment and pier centerlines. Whether this is done or not, the Contractor is responsible for the entire stakeout following the initial placement of the construction centerline. The Inspector should record the locations of the benchmark and control centerlines in the Project Diary. As the construction stakeout is developed by the Contractor, the Inspector should observe the process carefully to be assured that the procedures are accomplished properly. **[105.10]**

The Contractor should make a thorough check of the Project to identify all aerial or subterranean utilities that may exist in the area. These should be checked against those shown on the Plans and reviewed to see if others exist. When work is planned near utility locations, the Contractor is to inform representatives of those utility companies through “Miss Utility”. The Contractor is responsible for coordinating utility protection and relocation work with the utilities. **[105.09]**

When working near railroads, the Special Provisions of the Contract relating to railroad phases must be followed exactly. All work performed must be outside the required clearances established by the railroad, or the railroad should be advised promptly. Crossings or new crossings at grade, as well as excavations and cofferdams constructed adjacent to the railroad, are to be constructed in accordance with the regulations prescribed by the railroad. **[105.09]**

All materials to be used for structures must be approved. All approved materials that the Contractor plans to store on the Project site until they are used must be stored in accordance with the Specifications. **[106.07]** Subcontractors that are being considered for employment by the Contractor are to be approved prior to their starting work. Refer to Section B6.00 for additional information on materials and B7.00 for information on subcontractors. **[108.01]**

Prior to the erection of any formwork, the types of forms, their design, and the method of proposed erection is to be approved by the Engineer. **[602.08]** Shop drawings are to be submitted by the Contractor to the Department through the Engineer unless other arrangements are agreed to at the preconstruction meeting. **[105.04]**

No part of the structure is to be loaded before the time has elapsed as stipulated in the appropriate specification. This includes backfilling walls or stripping forms from horizontal concrete structures, such as bridge decks and sidewalks. Loading the structure or removing forms before the concrete has cured sufficiently may damage the structure. In extreme cases, the structure may fail or the life expectancy of the structure may be shortened. **[602.19]**

The following items should be accomplished by the Inspector before any structural work is begun:

- (a) Review the Plans and Specifications to understand the scope of the work.
- (b) Visualize how the structures will be constructed. Any construction items unfamiliar to the Inspector should be reviewed or discussed with the Engineer to clarify what will be done and what is expected of the Inspector.
- (c) Review the Contractor’s schedule for this work. Check to see that:
  - (1) The schedule includes all activities necessary to construct the structure.
  - (2) The durations of the activities seem reasonable.
  - (3) The sequence of work seems reasonable.

- (d) Determine if the required shop drawings have been submitted in accordance with the Specifications. **[105.04]**
- (e) Verify that all materials on site are being stored in accordance with the Specifications. **[106.07]**
- (f) Determine if any special equipment will be needed for inspection of the work.
- (g) Notify the Materials and Research Section that the structural work is beginning if they will need to be on site during the work.
- (h) Based on the Plans, Specifications, and Contractor's Schedule of Work, anticipate what items will need to be inspected and when that inspection will need to take place.
- (i) For work that will be performed on or near roads open to traffic, review the Contractor's safety and maintenance of traffic plans.

## SECTION E601 – TIMBER STRUCTURES

**E601.01 General.** This work consists of furnishing, treating, and constructing timber structures of treated, untreated, and structural glue-laminated (glulam) timber. **[601.03]**

The Inspector should ensure that all timber received has been inspected by the Materials and Research Section or its designated representative. All inspected material must contain a "hammer mark" stamp of approval. A record of such inspection must be maintained in the Project records. The Inspector is to inspect all timber materials or metal accessories to ensure that they are received in good condition and are as prescribed by the Plans and Specifications. **[601.05] [601.06] [601.07]** Timber structures are to be framed in accordance with the Plans. The Inspector is to review the Specifications before accepting minor cuts or borings after treatment. Areas that are cut or bored must be treated again by flooding with creosote, if specified. Timber materials should be handled carefully during erection to prevent damage.

## SECTION E602 – CONCRETE STRUCTURES

**E602.01 General.** This work consists of furnishing and placing portland cement concrete for structures and incidental construction.

The basic ingredients for concrete are cement, fine aggregate, usually in the form of sand, coarse aggregate, and water. The coarse aggregate may be proportioned into two sizes. The Engineer may authorize the elimination of the large coarse aggregate when, in the Engineer's opinion, the form or reinforcement design would prevent the use of such a large size aggregate. The coarse aggregate may be crushed stone or crushed air-cooled blast-furnace slag. Refer to Section E812 for additional information. **[805] [812.02]**

Certain admixtures may be specified for use in the concrete mix design for a structure. Generally, an air entrainment admixture is used in all concrete masonry. At times, a densifier, set retardant admixture, or accelerator admixture may be specified. Certain admixtures, such as carbon black or salt water resisting agents may also be required. The Specifications are to be carefully reviewed to ensure that only those admixtures authorized in the Specifications are used. **[812.02]** All types of admixtures not listed in the Specifications require the written authorization of the Engineer.

The concrete mix design is established by the Materials and Research Section. All materials used in the concrete must have prior approval from the Materials and Research Section.

Personnel from the Materials and Research Section will inspect and approve for use all concrete mix materials, the batch plant, the scales, and all batching operations. Records of these inspections will be maintained at the batch plant. Refer to Article 202 of the Materials and Research Manual of Procedures for additional information.

All concrete received on the site will be accompanied by a ticket signed by the Inspector assigned to the mixing plant. The receiving Inspector is required to complete the ticket by indicating the time the concrete is discharged from the truck and initialing the ticket upon receipt. **[812.06]** Refer to Subsection D2.05 for additional information.

The addition of mixing water to concrete is to be held to a minimum and should in no case exceed the limit set by the mix design water/cement (W/C) ratio. Based on the mix design W/C ratio and the indication on the batch ticket of how much water was added to the mix at the plant, the Inspector can calculate the maximum amount of water that can be added to the mix in the mixer truck on site. The W/C ratio is usually designed to be 5.6 gal (21.2 L) per sack of cement. Any addition of water must be done at the beginning of the batch. The batch must be mixed for 30 revolutions after adding water. Unless otherwise specified, the concrete can be truck mixed or central plant mixed. The Materials and Research Section usually monitors the mixing and delivery of all concrete. If the concrete does not arrive at the Project site in an acceptable condition, or within the required time, the Inspector is required to reject the load. Concrete is to be delivered in accordance with Subsection 812.06 of the Specifications, and is to be workable, consistent, and uniform. **[105.02]**

**E602.02 Formwork General.** Generally, fir plywood-faced forms are most acceptable. Concrete surfaces that will be given a rubbed surface cannot be formed with steel-faced forms unless otherwise specifically approved. **[602.08]**

The Inspector and the Contractor are to give careful attention to the details of form construction to obtain good concrete surfaces. The trueness, straightness, and sharpness of the lines on railing, copings, and curbs are to receive careful attention by the Contractor. Generally, structures are judged by the public based on the portions visible from the roadway. The entire appearance of an otherwise sound structure may be spoiled by poor alignment or workmanship on the visible parts.

**E602.03 Formwork Approval Procedure.** The Contractor is required to submit working drawings of all formwork to be constructed to the Engineer for approval. Construction of formwork may not begin until the formwork plans have been approved. Approval does not relieve the Contractor from the responsibility of constructing adequate, safe forms that conform to the Specifications. **[105.04] [602.08]**

If there is doubt as to the security and rigidity of the forms, the Inspector should instruct the Contractor to stabilize the forms. If the Contractor does not take corrective action, the Contractor is to be put on notice, in writing, of the possibility of unsatisfactory results. Form joints are to be made secure and tight to avoid unsightly offsets and mortar leakage. Forms should be set so the sheathing overlaps the concrete approximately 1" (25 mm). Sufficient tie bolts are required to hold the forms tight to the existing concrete during concrete placement and vibration. **[602.08]**

When placing the concrete, the forms are to be watched for signs of movement and are to be made secure where required. The surfaces of the forms are to be smooth, mortar tight, and free from holes and seams that would allow large amounts of mortar to escape, particularly at the

time of vibration. Form seams are to be tight to prevent accumulation of dirt prior to placing concrete or formation of mortar fins after concrete placement. **[602.08]**

Prior to placing concrete, the form surfaces are to be wet, oiled, or coated with approved materials. Coatings should not be so thick as to soften the concrete surface. A thin coating is all that is necessary to prevent the concrete from sticking to the forms. Oil should be applied to the forms before steel reinforcement is placed or the oil will stick to the reinforcement and destroy the bond between the reinforcement and the concrete. Coatings for forms should not stain the concrete.

Form tie appurtenances that are to be removed from the concrete after pouring may be lubricated with light oil; however, the use of grease is not allowed. Form ties and metal should be installed so that none is near an exposed surface and heavy enough to allow workers to climb on them. Twisted wire is to be used only on light work where liquid concrete will not exert significant force against the forms. Wooden spreaders should be removed as the concrete placement progresses. This may be accomplished by means of tag wires that have been previously attached. Holes for form ties are to be made as small as possible.

**E602.04 Procedure for the Inspection of Forms.** The inside and outside of forms are to be inspected before concrete placement is permitted to ensure that the forms are in the proper locations, of the proper size, and will support concrete within the required dimensions. Contractors are required to disassemble and reconstruct the forms if they have not been properly erected. **[602.08]**

Framework for structural concrete is to be carefully inspected and all dimensions measured. This is to be accomplished regardless of whether the framework is a calculated pay item or an estimated fixed quantity item. Inspectors are required to complete a Field Inspection Documentation form for each concrete pour. See Part H for a sample Field Inspection Documentation form.

The locations and dimensions of forms may shift or may not be the same as when they were built after they are filled with concrete. The weight of concrete, workers, and equipment used in placing concrete may cause the forms to settle, sag, or bulge. Supports, especially shores bearing on the ground, are to have an adequate bearing area. If settlement of the supports or sagging of the spans is expected, allowances should be made in the original construction of the forms. The Contractor should consider the widely used rule to camber the floor and beam forms  $\frac{1}{4}$ " (5 mm) per 16' (4 m) of span. In some cases, defined in Subsection 602.08 of the Specifications, the Contractor is required to camber the forms. The Contractor can use preventive measures such as adequate bracing and tying to keep the forms from bulging.

The table below provides some information for the maximum pressure that fresh concrete may exert on the forms when the concrete is vibrated.

**Table E-3: Tabulation of Vibrated Pressures**

Rate of placing (rise in ft/hr)	Depth at which maximum form pressure occurs, ft		Maximum form pressure (psf)	
	(at 70 °F)	(at 50 °F)	(at 70 °F)	(at 50 °F)
2	3.9	5.0	340	440
3	4.7	6.0	440	590
4	5.4	7.0	540	740
5	6.3	8.0	650	890
6	6.9	9.0	750	1040

**Table E-3M: Tabulation of Vibrated Pressures**

Rate of placing (rise in m/hr)	Depth at which maximum form pressure occurs, m		Maximum form pressure (kPa)	
	(at 21 °C)	(at 10 °C)	(at 21 °C)	(at 10 °C)
0.6	1.2	1.5	19.5	24.4
0.9	1.4	1.8	25.6	33.0
1.2	1.6	2.1	31.8	41.7
1.5	1.9	2.4	38.0	50.3
1.8	2.1	2.7	44.1	58.9

The Contractor is to exercise caution during the construction of the forms and when doing other related work inside the forms prior to placing concrete to avoid marring the form surfaces. Prior to reusing the forms, they should be wire brushed and, if necessary, reconditioned. Open seams are to be filled, warped boards planed or replaced, metal facings straightened, and all joints re-matched. All foreign materials such as chips, blocks, sawdust, dried mortar, and ice are to be removed from the forms with air, water, or steam. Foreign materials generally accumulate in corners and inaccessible places. The Contractor is to pay particular attention to cleaning these areas. In deep, narrow forms, holes for cleaning and inspection are to be provided at the bottom and at joint levels. The Contractor is to close all holes tightly before the concrete reaches them. **[602.08]**

**E602.05 Concrete Placement.** Before concrete is placed for a culvert or bridge deck, the cutoff screed must be tried across the entire form. The Inspector is to ensure that the Contractor performs a trial run with the screeds, checking all the vertical dimensions, clearances, and minimum thickness.

Handling and placing concrete is described in Section 602 of the Specifications. The Standard Specifications and the Special Provisions are to be reviewed prior to placement of concrete. The Inspector should pay particular attention to the weather and environmental conditions discussed in Subsection 602.10 of the Specifications. Conditions that may accelerate the evaporation rate of water in the concrete, such as low humidity, high temperatures, and high winds, should be addressed before placement begins. **[602.10]**

The items below are listed as a checklist and guidance for the Inspector:

- (a) All concrete is to be placed in the dry. There should not be any water in the forms except where tremie seals are intended.
- (b) All concrete is to be placed continuously from one designed elevation to the planned construction joint. Cold joints are not permitted.
- (c) The pouring rate or rise in feet (meters) per hour is not to exceed the rate for which the forms are designed. When using the same forms, this rate will vary with the daily temperature. The lower the temperature, the slower the concrete should be placed. Refer to Table E-3 in Subsection E602.04 for more information.
- (d) All concrete is to be consolidated with a mechanical vibrator in accordance with the Specifications. The Contractor should ensure that the concrete is sufficiently vibrated but is not over-vibrated. The vibration is for consolidation of the concrete mass only and is not to be used to move the concrete from one position in the forms to another position. The vibrator is to have sufficient amplitude. **[602.13]**

- (e) All forms are to be wet down just prior to placing the concrete. Make sure the Contractor has equipment available to accomplish this task. **[602.10]**
- (f) Placement of the concrete should be such that segregation of the aggregates does not take place. The Specifications are to be followed regarding the placement of troughs and chutes. Examples of proper placement techniques may be found in Subsection E602.12. The placement of concrete layers is to be carefully controlled, and the height of the layers is to be kept to that stated in the Specifications. **[602.10]** Aluminum chutes or pipes are not to be used to place portland cement concrete. The Inspector should notify the Contractor that no exceptions to this rule are allowed.
- (g) The Contractor should ensure that free running water or streams are not allowed to enter concrete footings from below the bottom elevation of the concrete to be placed.
- (h) All required shear keys are to be formed in accordance with the Plans.
- (i) All spreaders or other temporary fittings are to be removed as the concrete progresses upward. The Inspector is to ensure that the Contractor carefully keeps track of all the items and later accounts for them.
- (j) If segregation of material accidentally occurs, causing a rock pocket to form, the rock pocket is to be removed with shovels and equally distributed into the concrete.
- (k) All finishing is to be in accordance with the Specifications. Special attention should be given when finishing the surfaces of bridge decks, curbs, and sidewalks that are a part of the bridge deck. The Specifications outline bridge deck finishing procedures. **[602.20 (c)]** The Inspector should ensure that the Contractor follows the prescribed procedures. It is important that all surfaces are uniform and the alignment accurately checked before and after the placement of concrete. The Inspector should ensure that the Contractor has provided surface and aesthetic markings as specified. **[602.17] [602.20]**
- (l) All bridge bearing pads are to be surveyed to check the elevations before and after placing the concrete. Elevations are to be checked carefully and are to be within the specified range of accuracy. Form settlement, accidental bumping of the bearing pads, or dislodging of the bearing pads by materials or workers may have an affect on the elevation.





**Figure E-20: Structural Concrete Box Culverts**

**E602.06 Placing Concrete during Cold Weather.** During cold weather, the Inspector is to ensure that the Contractor observes the present and forecasted ambient temperatures so that any planned concrete operation is performed and protected as stated in the Specifications. [602.11]

**E602.07 Concrete Quality Control.** Quality control tests of portland cement concrete will be performed by representatives of the Materials and Research Section. That Section has procedures that specify the types of quality control tests to be performed, how the tests are to be performed, and the frequency of performing the tests. During placement of portland cement concrete for structures, the Materials and Research Section will perform the following operations on the Project site at predetermined intervals:

- (a) Sample fresh concrete.
- (b) Make and cure concrete compressive test specimens (see the Concrete Cylinder Sampling Tag and Form in Part H).
- (c) Perform slump tests.
- (d) Perform entrained air tests.

The Inspector should coordinate with the Materials and Research Section to ensure a Section representative is available to perform concrete tests and take samples according to the Contractor's schedule for placing concrete. When the tests have been completed, the Inspector should ensure that the recorded test results, along with the PCC ticket, are made a part of the Project's permanent records. A sample PCC ticket is shown in Part H. Typically, entrained air and slump test results will be available immediately in the field. Two compressive tests each are performed at 7 and 28 days. If early strength tests are needed, the Materials and Research Section

must be informed so that additional cylinders can be made. The Inspector should obtain these test results as soon as they are available and review them with the Contractor. Again, the Inspector must ensure that the compressive test results become a part of the Project's permanent records. A sample Concrete Compressive Strength Report is in Part H.

Concrete that fails to attain the required 28-day design strength, ( $f'_c$ ), is considered defective. Procedures for dealing with defective concrete are specified in Subsection 602.25 of the Standard Specifications. In addition, the Inspector should also check the Special Provisions for any additional or changed procedures.

**E602.08 Curing.** The term “curing” is applied to a set of conditions of moisture and temperature that has been established to ensure that proper hydration takes place. The critical curing period is the first 48 hours after the concrete has been placed, during which time the concrete is being transformed from the plastic to the desired hardened state. During the curing period, the concrete is to be protected from rapid drying and from rapid temperature changes. On all unformed surfaces, it is preferable to apply moisture continuously during the curing period, as described in the Specifications. All roadway surfaces of bridge decks and approach slabs must be water cured. Surfaces that are to receive waterproofing or an anti-graffiti material should not receive a curing compound. **[602.18] [602.20]**

Waterproof paper or membrane curing compounds may be employed to prevent moisture loss. The effectiveness of using these methods may be increased through the prior use of some form of moist curing, such as burlap. When moist coverings are applied, frequent inspections are to be conducted to ensure that the covering does not dry out and absorb the water from the concrete. Moist coverings are to be used when curing bridge decks. The Contractor should ensure that waterproof paper is free of holes, the seams are tight, and the edges are held down tightly to prevent air from entering. Membrane curing compounds are to be applied at the rate of coverage required in the Specifications. The Contractor is to ensure that the proper quantity of membrane curing compound is applied and spread evenly throughout. **[602.18]**

When working with formed surfaces that are to be cured with a liquid membrane compound following the removal of forms, the concrete is to be thoroughly sprayed with water after removal of the forms and prior to the application of the curing agent. When the Contractor is ready to begin applying the curing compound, it can stop spraying the concrete with water. The curing compound is to be applied as soon as the surface moisture on the concrete disappears. Formed surfaces that are not to be cured with a membrane curing compound are to be kept wet during the period between removal of the forms and the final curing date. Wood forms are to be kept damp for the entire curing period when left in place to prevent joints from opening and concrete from drying. **[602.18]**

**E602.09 Finishing.** Forms are to be removed within the period stated in the Specifications when the surface requires a rubbed finish. If the forms are not removed in a timely fashion, no additional concrete may be placed until all required stripping and rubbing has been completed in accordance with Subsection 602.17 of the Specifications. **[602.17] [602.19]**

Generally, most structural concrete requires a rubbed surface finish. The rubbing is performed with a series of carborundum stones of different coarsenesses. The Inspector should review the Specifications and ensure that the Contractor completes the first rubbing before the concrete has hardened in order to obtain the proper finish. The final rubbing, when completed, should give the structure a completed, uniform appearance and leave a pleasing white texture.

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After the final rubbing is complete and the surface has dried, the surface should be rubbed with burlap to remove any loose powder. [602.17]

**E602.10 Waterproofing.** Specifications for waterproofing concrete surfaces may require either superficial waterproofing or membrane waterproofing. The Inspector is advised to refer to the Special Provisions for information as to the type to be used and method of application.

Before application of waterproofing, the ordinary surface finish required by the Specifications should be accomplished on the concrete surface. The surface is prepared by filling all cracks and voids and removing all undesirable irregularities from the surface. [602.17]

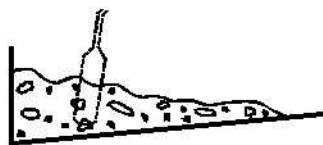
Waterproofing is to be accomplished when the weather is dry and the surface is dry and cured to the extent that no moisture exists in the concrete. Most waterproofing materials require the concrete to have cured for 28 days prior to their application. Only specified materials approved by the Materials and Research Section are to be used. Records must be on file to indicate approval prior to use. Care is to be taken that the materials are used only as specified, applying full coverage to the surface in the required number of applications.

**E602.11 Measurement and Payment.** The Inspector should review the quantity sheet contained within the Plans to verify whether the portland cement concrete item is a fixed quantity. If the quantity is fixed and the accuracy verified in the field, then payment will be made in accordance with Subsection 109.05 of the Specifications. If the quantity is not fixed, then detailed sketches used for computation of the volume must be made. Because portland cement concrete items are very high price items, precise measurements will be needed.

Reduction in payment due to low strength concrete is discussed in detail in Subsections 602.25 and 602.27 of the Specification. These subsections should be reviewed by the Inspector when portland cement concrete items are being constructed.

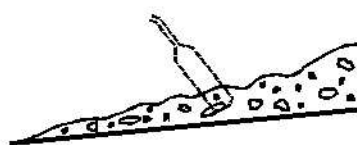
**E602.12 Examples.** The diagrams on the following pages highlight several common concrete placement situations, showing the correct and incorrect way to place the concrete. The Inspector should use these diagrams as a guide when observing concrete placement to ensure that the Contractor is not using any placement methods that decrease the strength or compromise the durability of the concrete.

## PLACING CONCRETE IN A SLOPING LIFT



**CORRECT**

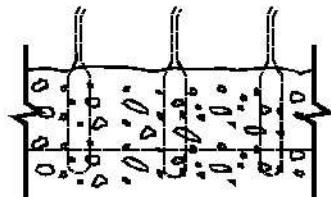
Start placing at bottom of slope so the compaction is increased by weight of new added concrete. Vibrator consolidates the concrete.



**INCORRECT**

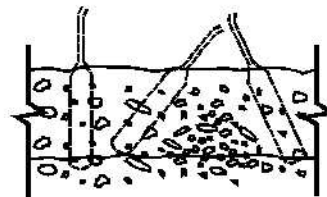
When placing is begun at top of slope, the upper concrete tends to pull apart especially when vibrated below as this starts flow and removes support from concrete above.

## SYSTEMATIC VIBRATION OF EACH NEW LIFT OF CONCRETE



**CORRECT**

Vertical vibration of vibrator about 2 to 3" (50 to 75 mm) into previous lift (which not yet be rigid) at systematic regular intervals will give adequate consolidation.



**INCORRECT**

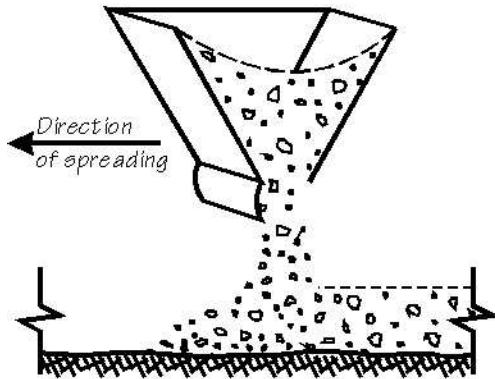
Haphazard random penetration of the vibrator at all angles and spacing without sufficient depth will not assure intimate combination of the two layers.

**Figure E-21: Ensuring Uniformity of Concrete Lifts**

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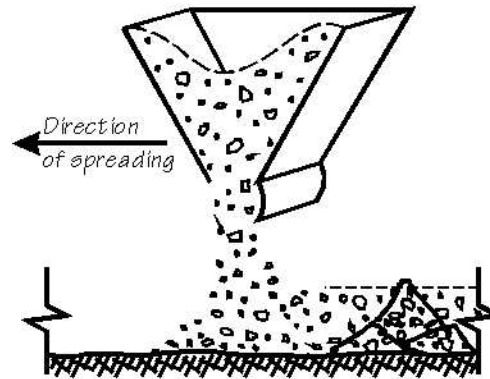
## IF SEPARATION HAS NOT BEEN ELIMINATED IN FILLING PLACING BUCKETS

*(A temporary expedient until correction has been made)*



CORRECT

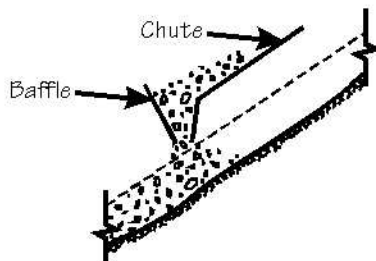
Bucket should be turned so that separated rock falls on concrete where it may be readily worked into mass.



INCORRECT

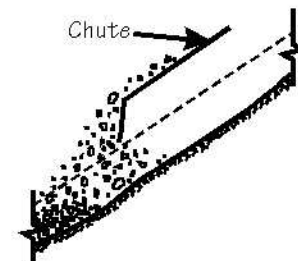
Dumping so that free rock falls out on forms or subgrade, resulting in rock pockets.

## PLACING CONCRETE ON A SLOPING SURFACE



CORRECT

A baffle and drop at end of chute will avoid separation and keep concrete on slope.

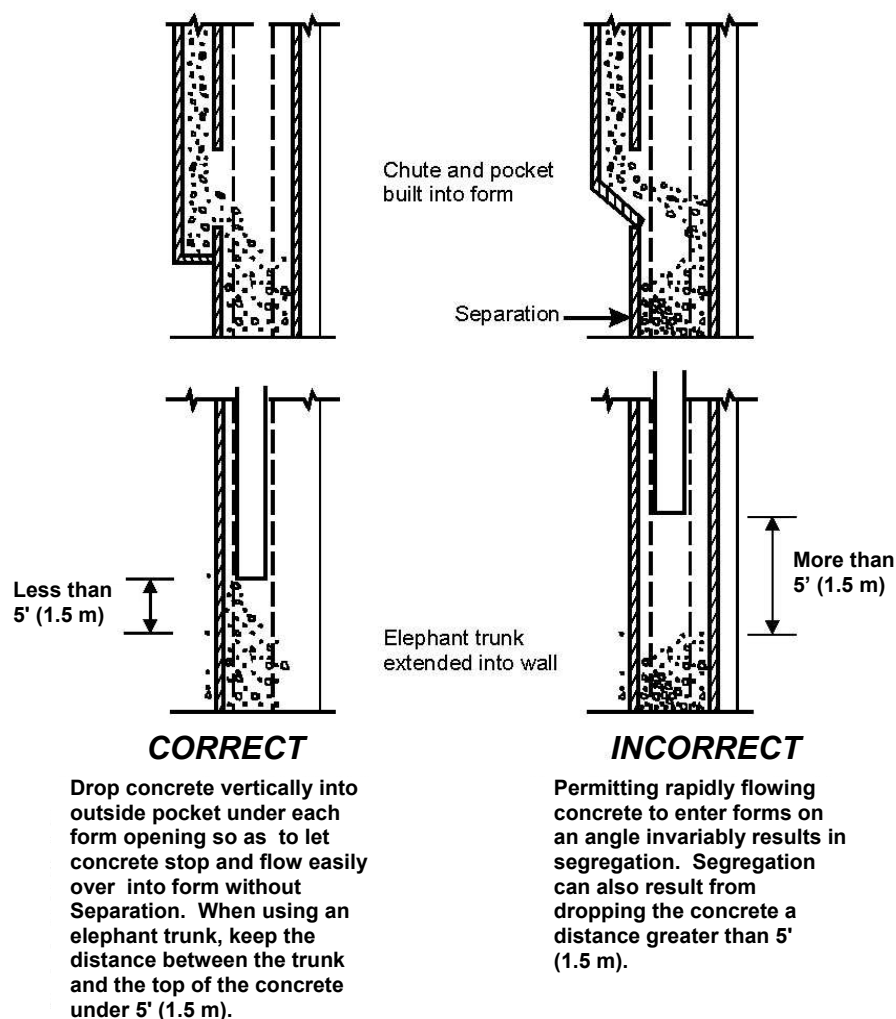


INCORRECT

Discharging concrete from free end chute onto a slope causes separation of rock, which goes to bottom of slope. Velocity tends to carry concrete down the slope.

**Figure E-22: Placing Concrete to Avoid Segregation**

### PLACING CONCRETE IN DEEP NARROW WALL



### PLACING STRUCTURAL CONCRETE WITH A CONCRETE PUMP

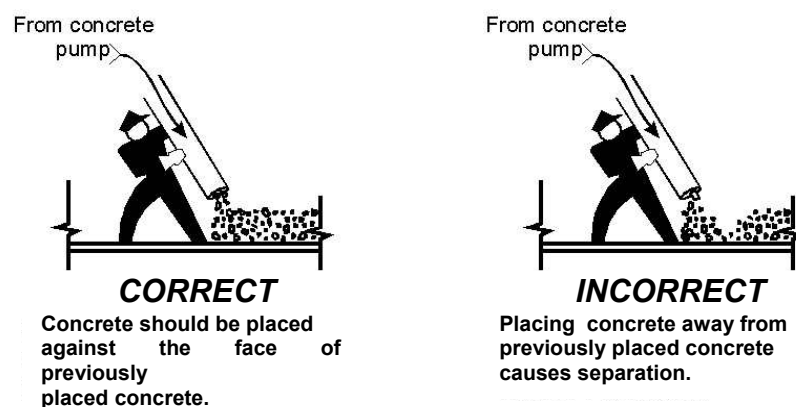


Figure E-23: Proper Concrete Placement with a Chute or Pump

## SECTION E603 – BAR REINFORCEMENT

**E603.01 General.** This work consists of furnishing and placing bar reinforcement.

Concrete may be reinforced with plain or deformed steel bars. With the exception of wire mesh, the Department uses only deformed bars to reinforce concrete. Generally, steel bars resist the tensile stress, or pull, to which a structural member is subjected, while concrete resists the compressive stress, or push. Occasionally, steel bars may be used to resist compressive forces in concrete. Concrete and steel are combined to resist the shear stress.

The term “bond” refers to the adherence of the concrete to the steel bars. The bonding must be sufficient to prevent slipping when a member is loaded or stressed. Throughout the United States, deformed bars, which cost about the same as plain bars, are used, because they have been found to develop a stronger bond than plain bars.

The effectiveness of concrete reinforcement depends on the position of the steel in the concrete. Reinforcing material must be placed carefully and accurately, as shown on the Plans. A slight variation in the position of the steel in the finished member, as compared with the design, greatly alters the condition of stability, strength, and safety.

**E603.02 Reinforcement Pre-Installation.** The Specifications are to be checked to ensure that the reinforcement material is in conformance with the Specifications. Material that is not used immediately is to be properly stored on wood platforms or other approved surfaces. Material is to be clean and free from mill scale, paint, grease, dirt, or oil. (A light film of rust is not objectionable.) [603.04] [824]

**E603.03 Reinforcement Inspection Procedure.** The Inspector should be prepared to start inspection procedures when the first bars are placed to ensure that the spacing, type, size, quantity, and other installation requirements are correct. If field bending of the material is required, it should be accomplished without heat. When checking bends, consider the outside face of the bend. The bar reinforcement is to be in the exact position shown on the Plans and is to be firmly supported and secured from displacement by the impact of the concrete when placed. Sub-assembly of reinforcement before placement into the forms is acceptable in some instances, but must be rigid and free from movement. [603.05]

The clearance required by the Plans or Specifications from the face of the forms is to be checked. When placing bar reinforcement for bridge decks, the clearance from the deck form to the bottom face of any reinforcement and the distance from the top bar to the deck form are both important measurements to check. Clearances are important to the ultimate strength of the structure and protection against moisture and fire. When reinforcement is placed too close to the surface in exposed areas, rust will form and the surface concrete will spall in a few years. [603.05]

Concrete spacer blocks that are made from good mortar and finished to the exact height are most desirable for supporting reinforcement steel from the ground in foundations. If blocks are used, they are to be placed with the formed side down and the floated side up to ensure a better bond to the concrete mass and that they will not be detected when the forms are removed. [603.05]

The Specifications state that metal chairs are not to be used if they are in direct contact with the forms, unless they are plastic or rubber tipped. Pebbles, bricks, broken stone, metal or wood blocks, and other unapproved material can not be used for blocking. Bar reinforcement is not to be shoved into plastic concrete after it has been placed. [603.05]

Welding reinforcement steel will not be permitted unless it is detailed on the shop drawings or approved in advance in writing, and in both instances, approved by the Engineer in writing. If welding is permitted, it is to be in accordance with the referenced specification of the American Welding Society and should never show burning on the surface of the bar or reduction in bar size. Refer to Subsections E605.11 and E605.12 for additional information.

In the event the Plans are revised or changes are made in reinforcement spacing, no substitution of bar size of the steel used or the addition of splices will be allowed, unless approved in advance by the Engineer.

The Inspector should ensure that the general appearance of reinforcement work is neat and that no omissions have been made in the field. Should additional steel be required, the Contractor should be advised as early as possible so that the extra steel may be ordered and placed without delaying the work. The Inspector is required to complete a Field Inspection Documentation form for each concrete pour. A sample of this form is in Part H.

**E603.04 Reinforcement in Cast-In-Place Piles.** Reinforcement that is placed in cast-in-place piles is to be made neatly and the reinforcement cage is to be inserted with care. The Inspector is to review with the Contractor the method to be used for securing the wire cage. The cage is to be secured and blocked so that it does not touch the steel pile shell, as this would introduce the possibility of reinforcement and pile deterioration due to electrolysis. The Specifications should be reviewed to determine whether the reinforcement is a non-pay item included in the price of the pile. [618.23]

**E603.05 Measurement and Payment.** Measurement and payment is made in accordance with the requirements of the Specifications. The Inspector is required to measure the work to establish payment. The measurement is to consist of a check of the dimensions of the bars both in the shipping bundles and as they are placed in position. A listing of all bars used is required to tabulate the actual number, length, and theoretical weight. All bars of the same diameter are summarized to determine the total length used to compute the theoretical weight.

The following table listing the properties of standard concrete reinforcing bars can be used to check the dimensions of the reinforcing bars on the Project. [603.08] [603.09]



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The bar designation shown on the Plans and Specifications will be either in English or metric units. The industry convention in the manufacture of reinforcement bar is to use the metric bar designation. The bar designation is indicated by raised numbering on each bar.

**Table E-4: Properties of Standard Reinforcing Bars**

Bar Designation No. <sup>A</sup>	Unit Weight	Nominal Dimensions <sup>B</sup>			Deformation Requirements (in)		
		Diameter	Cross-Sectional	Perimeter	Maximum Average	Minimum Average	Maximum Gap (Chord of 12.5% of Nominal Perimeter)
English (Metric)	(lb/ft)	(in)	Area (sq in)	(in)	Spacing	Height	
#3 (#10)	0.376	0.375	0.11	1.178	0.262	0.015	0.143
#4 (#13)	0.668	0.500	0.20	1.571	0.350	0.020	0.191
#5 (#16)	1.043	0.625	0.31	1.963	0.437	0.028	0.239
#6 (#19)	1.502	0.750	0.44	2.356	0.525	0.038	0.286
#7 (#22)	2.044	0.875	0.60	2.749	0.612	0.044	0.334
#8 (#25)	2.670	1.000	0.79	3.142	0.700	0.050	0.383
#9 (#29)	3.400	1.128	1.00	3.544	0.790	0.056	0.431
#10 (#32)	4.303	1.270	1.27	3.990	0.889	0.064	0.487
#11 (#36)	5.313	1.410	1.56	4.430	0.987	0.071	0.540
#14 (#43)	7.65	1.693	2.25	5.32	1.185	0.085	0.648
#18 (#57)	13.60	2.257	4.00	7.09	1.58	0.102	0.864

**Source: ASTM A 615/A 615M – 01b**

<sup>A</sup>Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars (bar numbers approximate the number of millimeters of the nominal diameter of the bar).

<sup>B</sup>The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

**Table E-4M: Properties of Standard Reinforcing Bars**

Bar Designation No. <sup>A</sup>	Unit Weight	Nominal Dimensions <sup>B</sup>			Deformation Requirements (mm)		
		Diameter	Cross-Sectional	Perimeter	Maximum Average	Minimum Average	Maximum Gap (Chord of 12.5% of Nominal Perimeter)
English (Metric)	(kg/m)	(mm)	Area (mm)	(mm)	Spacing	Height	
#3 (#10)	0.560	9.5	71	29.9	6.7	0.38	3.6
#4 (#13)	0.994	12.7	129	39.9	8.9	0.51	4.9
#5 (#16)	1.552	15.9	199	49.9	11.1	0.71	6.1
#6 (#19)	2.235	19.1	284	59.8	13.3	0.97	7.3
#7 (#22)	3.042	22.2	387	69.8	15.5	1.12	8.5
#8 (#25)	3.973	25.4	510	79.8	17.8	1.27	9.7
#9 (#29)	5.060	28.7	645	90.0	20.1	1.42	10.9
#10 (#32)	6.404	32.3	819	101.3	22.6	1.63	12.4
#11 (#36)	7.907	35.8	1006	112.5	25.1	1.80	13.7
#14 (#43)	11.38	43.0	1452	135.1	30.1	2.16	16.5
#18 (#57)	20.24	57.3	2581	180.1	40.1	2.59	21.9

**Source: ASTM A 615/A 615M – 01b**

<sup>A</sup>Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars (bar numbers approximate the number of millimeters of the nominal diameter of the bar).

<sup>B</sup>The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same mass per meter as the deformed bar.

## **SECTION E604 – BAR REINFORCEMENT, EPOXY COATED**

**E604.01 General.** This work consists of furnishing and placing epoxy coated bar reinforcement.

Epoxy coating is typically used on bar reinforcement in bridge decks that will be exposed to de-icing salt. Salt can corrode the bar reinforcement over time. The epoxy provides a protective cover to the bar reinforcement to prevent salts from corroding the metal. Therefore, it is very important that the coating be protected until the bars have been placed and the concrete has been poured. The Inspector must verify that all epoxy bar bundles have a tag attached that states that the coating has been inspected and approved.

Many of the requirements for standard bar reinforcement discussed in Section E603 above also apply to epoxy coated bar reinforcement. The Inspector should refer to Section E603 any time epoxy coated bar reinforcement is used on the Project.

**E604.02 Storage and Protection.** Like standard bar reinforcement, epoxy-coated bars are to be stored off the ground on wood or padded supports. In addition, epoxy-coated bar reinforcement that has been exposed to sunlight for 90 days must be covered by the Contractor. [604.05]

To protect the epoxy coating, bundles of bar reinforcement should be handled only with padded or non-metallic slings. The bar reinforcement should not be dropped or dragged, and should be lifted by spreader bars or multiple supports to prevent the bars from rubbing against one another. If the Inspector observes the Contractor using improper handling practices, the Inspector should suspend the work, have the Contractor handle the bar reinforcement properly, and check the bar reinforcement to determine if the epoxy coating has been damaged. [604.05]

**E604.03 Placing.** Epoxy-coated bar reinforcement for bridge decks is to be supported in the forms by continuous type supports and additional bar chairs where necessary. All bar supports that come in contact with the bar reinforcement must be epoxy or plastic coated and must be approved by the Engineer. The Inspector should verify that the coating on the bar supports is not damaged. [605.08]

**E604.04 Repair of Epoxy Coating.** The Engineer may reject any bar reinforcement if it appears that the epoxy coating has been damaged. The Inspector should bring any bars that appear to be damaged to the Engineer's attention. The Contractor may either repair or replace rejected bar reinforcement. The Inspector should verify that no rejected bar reinforcement is placed until it has been repaired. The Inspector also should ensure that repairs are made in accordance with the requirements of the Specifications. [604.08]

## **SECTION E605 – STEEL STRUCTURES**

**E605.01 General.** This work consists of furnishing, field fabricating, erecting, and painting structural steel for bolted and welded construction. This work also consists of recoating a portion of or the entire existing steel structure.

Structural steel is usually inspected in the shop for materials composition and fabrication accuracy by a consultant inspection firm. The Inspector should determine whether this method of inspection has been authorized for the Project. Inspection reports for all fabricated steel are to be on file in the field office prior to erection. The Inspector should ensure that the fabricated steel has not been damaged in transit. If any steel was damaged in transit, the Inspector should ensure that the damage has been documented. Before erection starts, all anchor

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bolts are to be inspected for position and elevation. The Contractor may grind the concrete bearing pads with an approved surfacing machine to their precise elevation and to a uniform horizontal plane. Each pad should be checked for elevation with an engineering level at only one point. The bearing pad should then be checked using a carpenter's level for a smooth level plane in all directions.

Proposed corrective action for bearing pads that are damaged or low in elevation must be approved by the Engineer.

The plans for steel structures are to be studied prior to erection. The dimensions of all the members are to be checked against the detail drawings. All welds should be inspected for size and quality. When welding is performed in the field, the joint to be welded is to be checked against the detail drawings. Shop painting is to be inspected after the steel arrives at the Project site. The Contractor is to be cautioned against mixing damaged members or those requiring repair with those in good condition. In addition, the Contractor is to be encouraged to expedite repair or replacement of all damaged members.

**E605.02 Delivery and Storage of Materials.** The Contractor is to ensure that the delivery of all structural steel materials is accomplished in such a manner as to prevent or minimize damage. Nylon or a similar type of sling around the members is recommended as a means of loading and unloading structural steel that will not damage shop coatings. Wood softener blocks should be used to prevent damage to flanges, finished pinholes, and field connection holes.

Materials are to be stored in a well-drained area, free of vegetation and debris. During storage, members are to be placed on wooden blocks, platforms, or skids that keep the material off the ground and above any probable water level. All beams and girders are to be placed in the upright position, braced to prevent overturning, and, if cambered, should rest on the lower flange. At this time, the Inspector should check and record the camber to ensure compliance with the Plans. Members are also to be transported and handled in the upright position. Authorized repairs and straightening of members are to be supervised by the Inspector in accordance with the Specifications. Repairs are to be completed prior to incorporating the member in the structure.

**E605.03 Falsework.** Inspection of falsework begins with checking the falsework working drawings. They must bear the seal of a Professional Engineer registered in Delaware. These working drawings must be approved by the Department before falsework construction begins. Although the Contractor's Professional Engineer must certify that the falsework has been constructed according to the approved falsework drawings, the Inspector should check the condition and size of the materials used against the approved drawings. [605.27] [105.04]

**E605.04 Erection of Structures.** Prior to the start of erection, a longitudinal and transverse centerline or working line is to be scribed on all substructure units. Elevations are to be taken immediately at the start of erection. During the course of erection, any deviation from the working line or elevation is immediately to be brought to the attention of the Contractor for correction. Camber diagrams are to be furnished with erection plans, and the proper camber should exist prior to the start of any bolting. The Specifications have specific requirements for

placing camber in trusses. The Inspector should ensure that the Contractor complies with these requirements. Bearing surfaces and surfaces in permanent contact must be cleaned by the Contractor before any structural members are assembled. [605.24] [605.31]

**E605.05 Punched Holes.** Punched holes in members are to be carefully inspected for size and shape before the start of erection. Any holes that are oversized or distorted in shape are to be marked for reaming and a record kept for later reference and re-inspection. The Contractor is to be immediately informed so it can implement corrective action. [605.07]

**E605.06 Match-marking.** The members that have been match-marked are to be assembled exactly as indicated on the match-marking diagram. No deviation from the original order of assembly is to be allowed. As erection progresses, the Inspector should compare the assembled members against the erection plans to ensure that the correct members are in the correct positions. [605.31]

**E605.07 Assembly.** Both the Contractor and Inspector should be on the alert to ensure proper safety procedures are always practiced by personnel on the Project site. The Contractor should understand the importance of proper guying and bracing of members against wind gusts, and that all anchor bolts should be double-checked to ensure proper size, location, and elevation. The members of a steel structure should assemble easily without using an excessive amount of force. Hammering and beating on steel members is largely wasted motion and may be an indication of a problem with the manufacturing or assembly of the members. Hammering that injures or distorts the members is not allowed. The use of small jacks to spread gusset plates to enter other members will accomplish the desired results and prevent damage. [107.06] [108.06] [605.31]

The cross frames, laterals, and wind bracing are to be erected along with the main span members. Simple beam and girder spans, including diaphragms, laterals, cross frames, and wind bracings, should be completely erected, pinned, and temporarily bolted before any final bolting has commenced. Half of the holes in splices and field connections should be filled with pins and bolts before high-strength bolts are installed. Some connections may require more pins and bolts. The erection plans should be checked for such instances. Erection bolts must be tightened with long-handled wrenches or power wrenches.

During erection, the Inspector should ensure that the Contractor uses turned bolts or high strength bolts as required by the erection plans or the Specifications. Should a question arise as to the type of hardware to be used, the matter should be referred to the Engineer for resolution.



**Figure E-24: Placing a Steel Girder**

***HISTORICAL PERSPECTIVE***

High-strength bolts are a relatively recent innovation in steel assembly. In the early 1900's, steel was assembled using rivets. Rivets are no longer used in Delaware. However, some DelDOT projects involve replacing rivets with high-strength bolts. The following text was taken from DelDOT's 1974 Construction Manual, and may prove useful to Inspectors working on rivet-replacement projects.

**Riveting**

The Inspector should check the rivets at each point before the riveting scaffold is removed. Burning holes with a torch, burning out defective rivets, gouging holes with a drift pin, and/or tightening of rivets by caulking the heads shall not be allowed. Rivets should be tested for looseness with a small hammer, by striking one side of the rivet head while holding a drift pin, nut, or washer against the other side. (Slight looseness of rivets cannot be detected by sound or visual inspection.) Defective rivets are to be penned or marked to identify them for removal or replacement. Rivets are to be checked after driving, to assure that heads are up tight to the metal, that the heads are in alignment, properly spaced, and that the rivet has not been burned. (The specifications require the Inspector to inspect all bolts.) A record is to be maintained of all defective rivets or bolts so that they may be located for re-inspection or should the areas be spot painted prior to corrective action.

Defective rivets may be removed by breaking off the heads with a "rivet buster" or with a square-nosed side cutter and maul. After the head is removed, the rivet may be driven out with a steel pin, or removed with a "backing-out" tool or other approved method (if necessary, rivets may be drilled out). (The Contractor must be careful when removing rivets so as not to harm the surrounding metal.)

**NOTE**

At times, when a defective rivet is removed, surrounding rivets may be loosened. Inspectors are advised to recheck the surrounding rivets after replacement has been completed of defective rivets. Faulty temporary bolting is a usual cause for loose rivets. The Contractor should be advised to use a sufficient number of bolts to hold members tightly together during riveting.

**E605.08 Bearings and Anchorages.** The Contractor is required to exercise extreme care in the final positioning of rocker bearings used in expansion joints on steel structures. Unless otherwise specified, these rockers in the final position should be vertical under a full dead load at a temperature of 68° F (20 °C). The Inspector is required to witness the setting of these rockers to ensure that they will be plumb at this temperature. This setting is to be accomplished using the coefficient of expansion for structural steel in conjunction with the temperature in the shade of the structural steel at the time of installation, using the length of span from the fixed point to the point of consideration. The final adjustment may be made after the bridge deck concrete is in place and the forms are stripped.

The Contractor is not permitted to do the necessary welding required to anchor the steel base plate in its proper position until the angles of inclination are approved by the Inspector.

The formula below is to be used for calculating the maximum variation from perfect alignment for rocker and segmental roller bearings with a height of 12" (300 mm) or less, considering the effect of temperature and load at the time of measurement.

### **ENGLISH**

$$M = \pm \left( 1/2" \times \frac{L}{14000} \right)$$

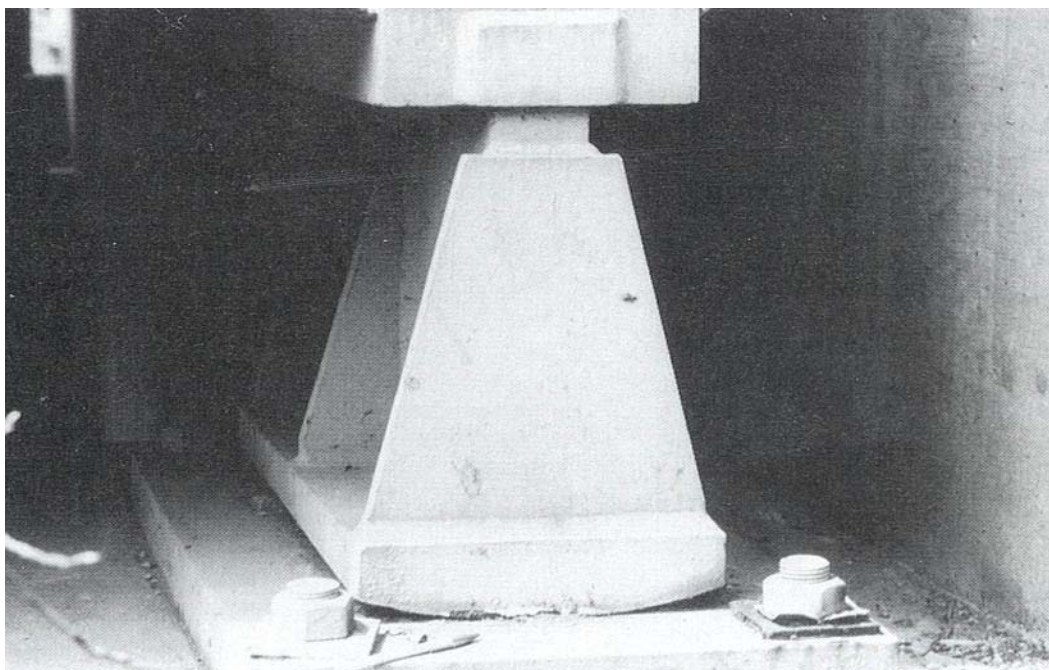
Where: M = maximum variation from perfect alignment in inches, measured as the horizontal distance between the centerline of the sole plate and the centerline of the masonry plate (see Figure E-12).  
L = length of the span in inches.

### **METRIC**

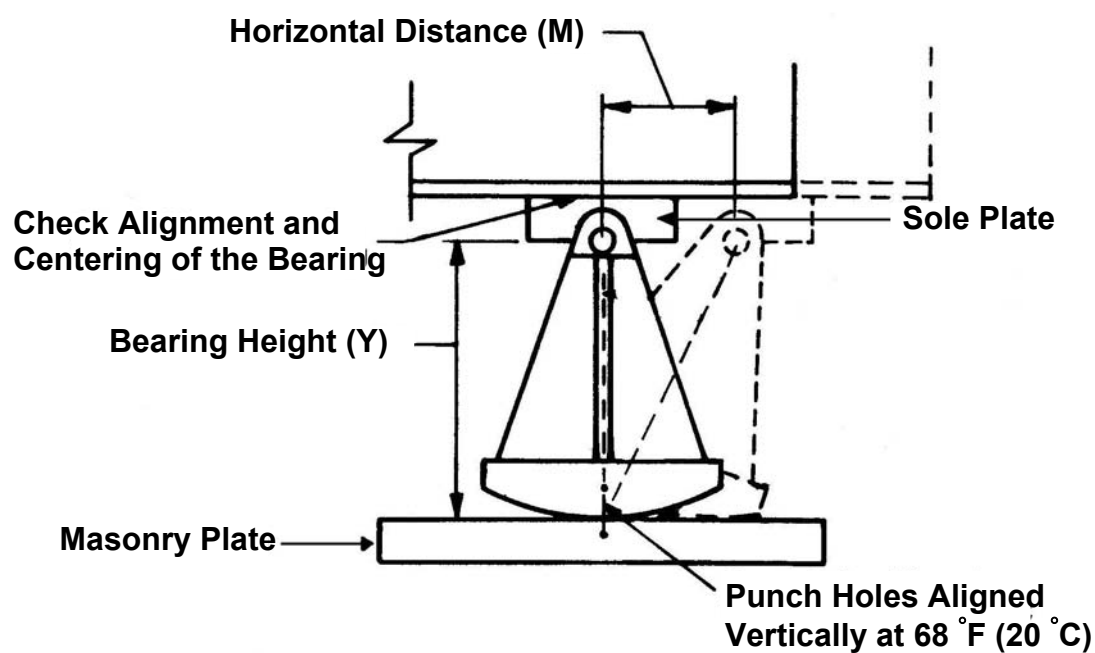
$$M = \pm \left( 12.7\text{mm} \times \frac{L}{35\,000} \right)$$

Where: M = maximum variation from perfect alignment in millimeters, measured as the horizontal distance between the centerline of the sole plate and the centerline of the masonry plate (see Figure E-12).  
L = length of the span in millimeters.





**Figure E-12: Typical Rocker Bearing**



**Figure E-26: Rocker Bearing Alignment Diagram**

Such variations are not to exceed a 1" (25 mm) offset. The total expansion length is the distance from the fixed bearing from which motion must progress. The bearing height is the distance between the upper and lower contact surfaces of the movable portion of the bearing.

For sliding bearings, the maximum variation from perfect alignment between the centerline of the fixed and movable portions of the bearing device, considering the effect of the temperature and load at the time of measurement, is to be  $\pm 1/4"$  ( $\pm 6$  mm), provided the movable

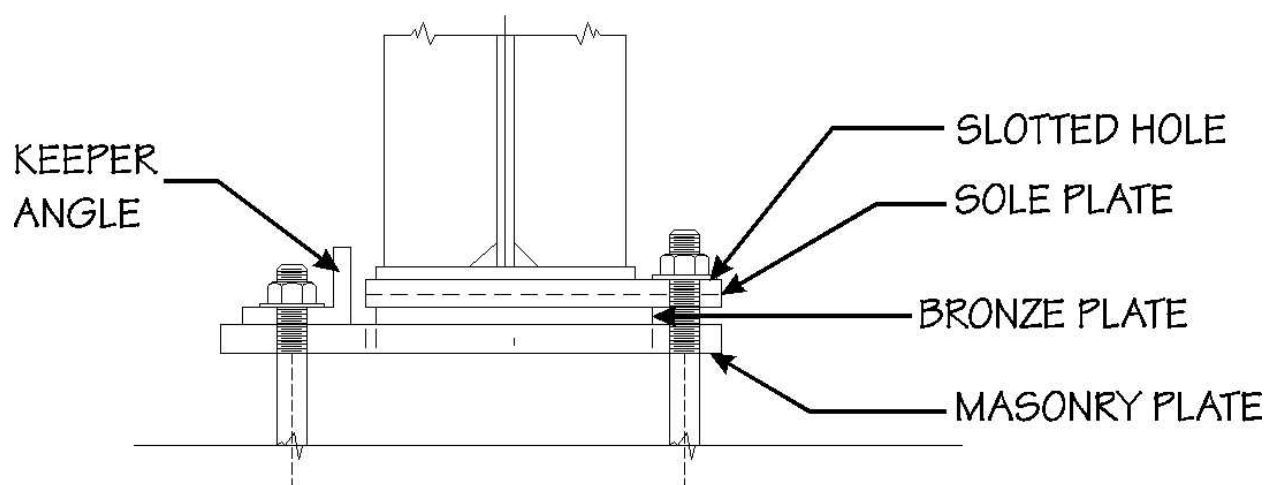


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portion of the bearing device is fully supported by the fixed portion under all temperatures and loading conditions.

When anchor bolts are set in the substructure prior to erection of the superstructure, they should be set with extreme care concerning the line and location. It is also necessary that the bolts project from the substructure as shown on the Plans. A template with holes for the anchor bolts should be constructed and securely nailed into the proper position. The anchor bolts should be placed in the template prior to embedding the anchor bolts in concrete. After the concrete has been placed and the initial set has occurred, the templates are to be removed and the top of the concrete finished at a level surface to give full bearing to the bearing plate.

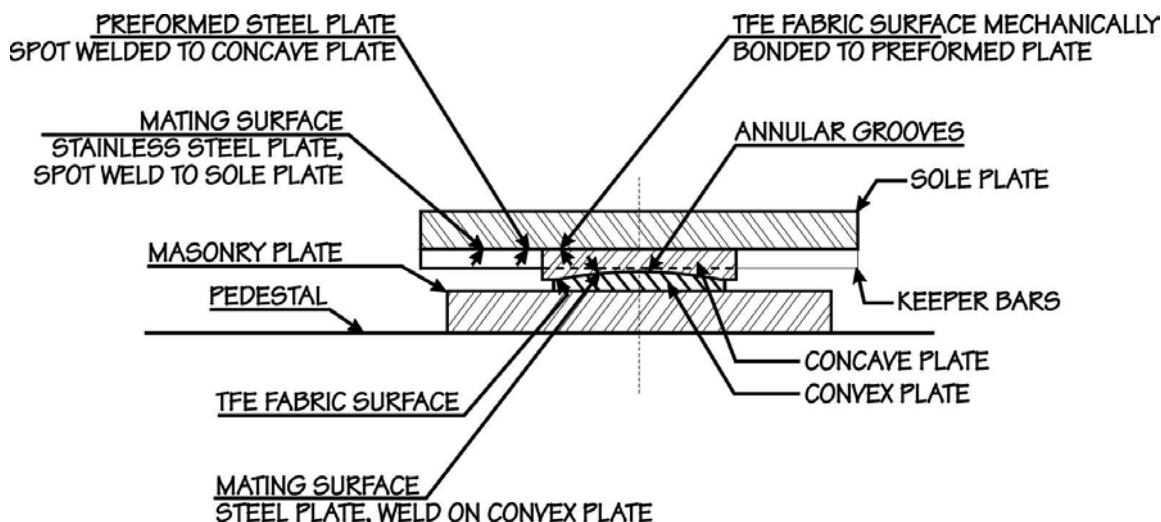
The following diagrams illustrate two of the most commonly used types of bearings. The Inspector should be familiar with the parts of these bearings in order to ease identification and inspection.



**Figure E-27: Steel Expansion Bearing**  
(note: anchorage is by either left or right method)

Anchor bolts that are set after the superstructure has been erected require caution in the drilling of bolt holes. The holes are to be drilled plumb and to the required depth. **[605.29]**

For structures on which anchor bolt holes are predrilled in concrete but are not immediately filled and sealed with the final planned material, the holes must receive special treatment and consideration if they are not sealed during cold or freezing weather. Under such conditions, it is very important that the openings be temporarily but completely sealed until they are permanently filled or until the cold weather season passes. There are several acceptable ways to temporarily seal this type of drilled hole. One method is to clean and dry the hole and fill it with a very dry sand to within 1" (25 mm) from the top. Seal the remainder of the hole to a height slightly above the top of the hole with an asphalt material that will be watertight. During cold weather, the Inspector should be alert for any type of opening in the substructure in which water may accumulate and cause damage by expansion during a freeze cycle.



**Figure E-28: Rotational Bearing**

**E605.09 Expansion Dams.** Expansion dams are manufactured to meet the proposed crown of the roadway of the particular bridge on which it is to be installed. Care is to be taken during the unloading and handling of expansion dams so as not to distort their shape. The expansion dam is supported by angles welded on the vertical section of the device. Holes are drilled through these angles and corresponding holes are drilled in the floor beams for fastening. The expansion dam should be set into position, and elevations should be taken at the support points. These elevations are then compared to the thickness of the shim required between the expansion device support angle and the floor beam. The longitudinal clear distances for expansion joints are to be adjusted for a temperature of 68 °F (20 °C) to correspond with the clear distance shown on the Plans, unless otherwise specified. The Contractor should take the necessary action to ensure that this work is accomplished with precision and care.

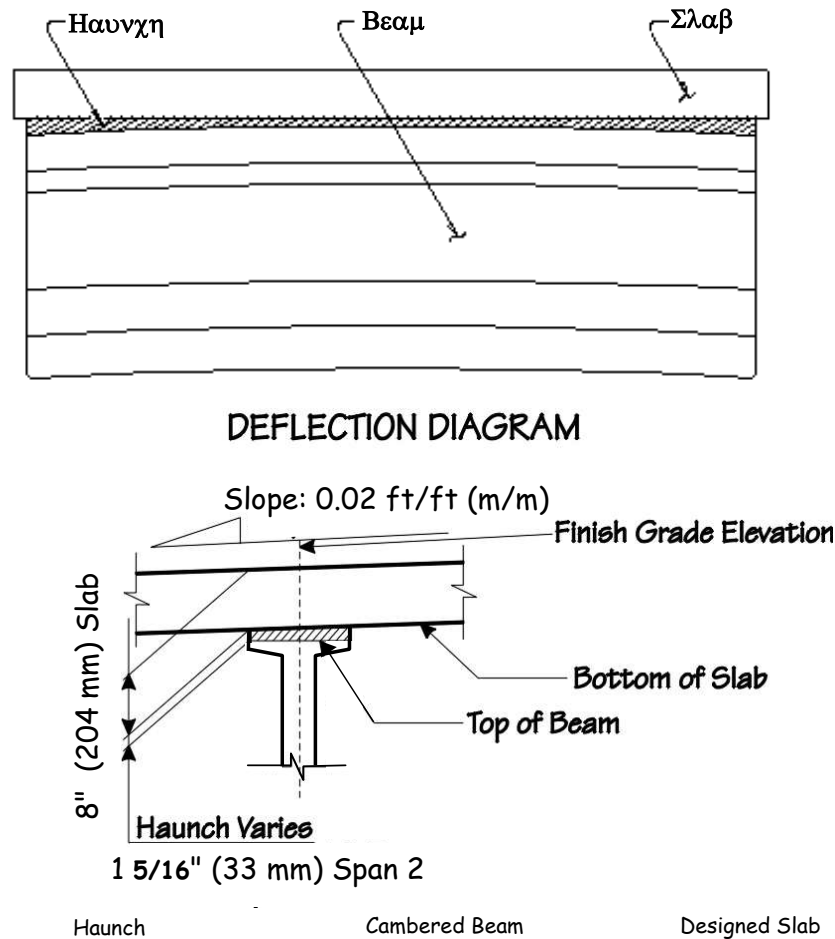
**E605.10 Grade Control for Bridge Decks.** Structural steel is elastic and will deflect when temporary or permanent loads are applied. Specifications for structural steel bridges having concrete decks usually require the concrete deck to be constructed with a uniform thickness. Consideration is to be given to the anticipated deflection of the structural steel to produce the desired smooth theoretical profile for the roadway surface. The Inspector is to maintain close grade control on the bridge deck to ensure a uniform deck thickness. **[105.02] [602.20]**

As soon as the steel is erected, points are located on top of the stringers that will indicate the centerline of piers and the quarter span and half span locations. The above span locations are to be marked so that they will not be lost during bad weather. Center punches or a chisel may be used for this purpose, and the locations may then be marked with a paint stick. After the structural steel has been fully bolted or welded as required in a particular erection unit, the existing elevations are to be taken on top of each of these points and recorded. An appropriate time should be selected to take these measurements prior to placing temporary loads, such as wood forms, being applied to the structural steel, but after the completion of the required assembly. The time for reading and recording the elevations should be on a day that no sun is shining or as early in the day as possible, before heat build up from the sun occurs on the top flange of stringers. Stringers will deflect upward or downward when the top flanges are in the direct sunlight.

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The following procedure should be used for grade control when constructing bridge decks:

- (a) After the existing elevation has been measured for each control point, the Inspector should review the Plans for the anticipated dead load deflection during the deck pour and the finish grade elevation along the roadway surface. In the following example, the anticipated dead load deflection is  $7/8"$  (22 mm) for span 2. The slab thickness is 8" (204 mm), and the finish grade of the slab is 0.02 ft/ft (0.02 m/m).

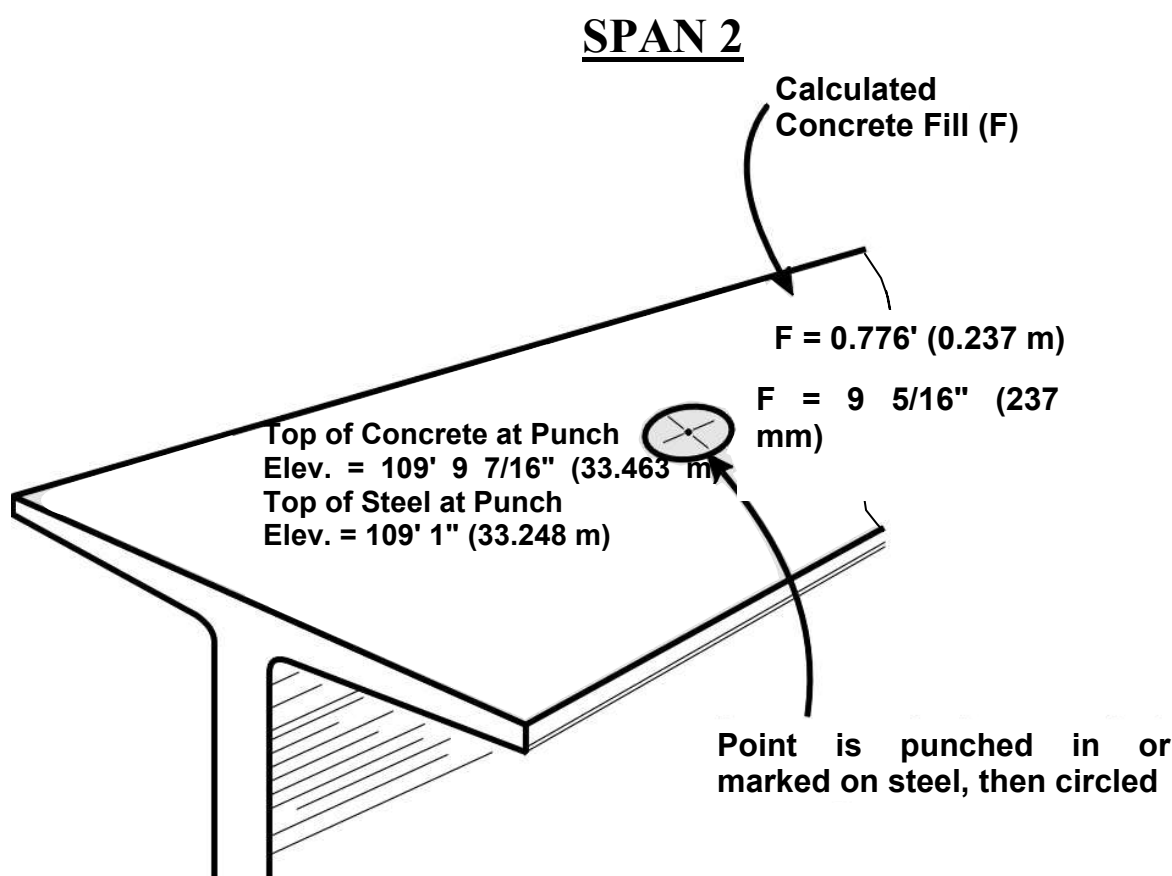


**Figure E-29: Sample Deflection Diagram**

(b) The concrete fill at each point is then calculated. First, the theoretical deflection is subtracted from the field-measured top of beam elevation. Next, the deflected top of beam elevation is subtracted from the finish grade elevation of the bridge roadway to find the depth of concrete fill required above each control point.

$$\begin{aligned}\text{Deflected Beam Elevation} &= \text{Undeflected Beam Elevation} - \text{Beam Deflection} \\ &= 109' 1'' - 7/8'' = 109' 1/8'' \\ &= 33.248\text{m} - 0.022\text{m} = 33.226\text{ m}\end{aligned}$$

$$\begin{aligned}\text{Calculated Concrete Fill (F)} &= \text{Finish Grade Elevation} - \text{Deflected Beam Elevation} \\ &= 109' 9\ 7/16'' - 109' 1/8'' = 9\ 5/16'' \\ &= 33.463\text{ m} - 33.226\text{ m} = 0.237\text{ m}\end{aligned}$$

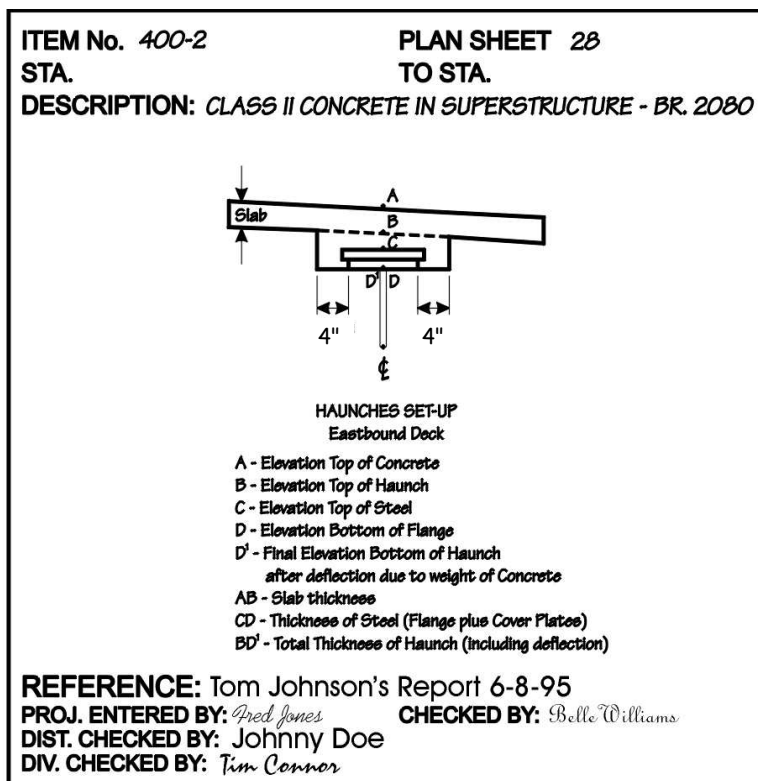


**Figure E-13: Sample Concrete Fill Calculation**

(c) Next, the concrete fill measurement is used to calculate the haunch thickness above each control point. The actual haunch thickness is found by subtracting the designed deck thickness from the calculated concrete fill measurement. In the example in Figure E-29 the haunch thickness is 1 5/16" (33 mm) for span 2.

$$\begin{aligned}\text{Haunch Thickness} &= \text{Calculated Concrete Fill} - \text{Design Deck Thickness} \\ &= 9 \frac{5}{16}'' - 8'' = 1 \frac{5}{16}'' \\ &= 0.237\text{m} - 0.204\text{m} = 0.033 \text{ m}\end{aligned}$$

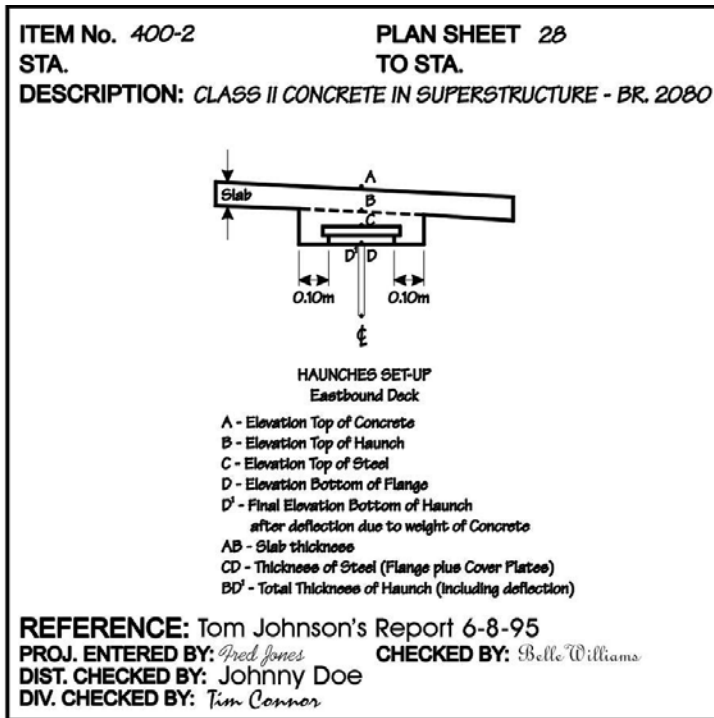
- (d) It is recommended that the Inspector record the field measurements, theoretical plan data, and calculations for the control points along each beam in the following manner.



BEAM NO.	POINT	1. Elev. Top Conc. Plan (ft)	2. Elev. Top Steel Field Measure (ft)	3. Diff 1-2 (ft)	4. Steel thic. - flg. + cover plate (ft)	5. Slab Deflection from Plans (ft)	6. Total Thickness 3+4+5 (ft)	8. Haunch Thickness 8a 8b	9. Haunch Width	10. Length b/t pts.	11. Volume b/t pts. 8x9x10
S-11	Abut E B-1	164.856	164.094	0.762	0.079		0.841	0.194			
S-11	A	164.448	163.822	0.626	0.079	0.059	0.764	0.174	0.184	2.579	35.000
S-11	B	164.097	163.458	0.639	0.079	0.030	0.748	0.157	0.167	2.579	35.000
S-11	Bent E B-1	163.848	163.162	0.686	0.112		0.798	0.207	0.180	2.579	24.000
S-11	C	163.569	162.837	0.692	0.069	0.020	0.781	0.164	0.184	2.579	27.999
S-11	D	163.280	162.588	0.692	0.069	0.050	0.811	0.220	0.194	2.500	28.501
S-11	E	162.998	162.290	0.708	0.069	0.020	0.797	0.207	0.213	2.579	28.501
S-11	Bent E B-2	162.739	162.063	0.617	0.098		0.715	0.184	0.197	2.579	25.000
S-11	F	162.480	161.863	0.617	0.069	0.020	0.706	0.115	0.151	2.579	25.000
S-11	G	162.191	161.515	0.676	0.069	0.050	0.795	0.269	0.161	2.579	28.501
S-11	H	161.899	161.276	0.623	0.069	0.020	0.712	0.121	0.164	2.579	28.501
S-11	Bent E B-3	161.571	160.948	0.623	0.112		0.735	0.144	0.135	2.579	27.999
S-11	J	161.273	160.626	0.597	0.079	0.030	0.706	0.164	0.154	2.579	25.000
S-11	K	160.879	160.282	0.597	0.079	0.050	0.726	0.144	0.154	2.579	35.066
S-11	Abut E B-2	160.531	159.849	0.682	0.079		0.761	0.171	0.157	2.579	35.066
S-12	Abut E B-1	164.619	163.930	0.689	0.089		0.778	0.187			
S-12	A	164.261	163.628	0.633	0.089	0.021	0.743	0.200	0.187	2.169	35.066
Page Total											193.94
											2

Figure E-31: Sample Field Record for Concrete Fill Calculations

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BEAM NO.	POINT	1. Elev. Top Conc. Plan (m)	2. Elev. Top Steel Field Measure (m)	3. Diff 1-2 (m)	4. Steel thic. - flg. + cover plate (m)	5. Slab Deflection from Plans (m)	6. Total Thickness 3+4+5 (m)	8. Haunch Thickness 8a 8b	9. Haunch Width	10. Length b/t pts.	11. Volume b/t pts. 8x9x10
S-11	Abut E B-1	50.251	50.016	0.220	0.024		0.259	0.059			
S-11	A	50.124	49.933	0.190	0.024	0.018	0.233	0.053	0.056	0.786	10.668
S-11	B	50.017	49.822	0.200	0.024	0.009	0.228	0.048	0.051	0.786	10.668
S-11	Bent E B-1	49.941	49.752	0.210	0.034		0.243	0.063	0.055	0.786	7.620
S-11	C	49.856	49.653	0.200	0.021	0.006	0.250	0.050	0.056	0.786	8.534
S-11	D	49.768	49.557	0.210	0.021	0.015	0.247	0.067	0.059	0.762	8.687
S-11	E	49.682	49.466	0.220	0.021	0.006	0.243	0.063	0.065	0.786	8.687
S-11	Bent E B-2	49.605	49.397	0.210	0.030		0.256	0.056	0.060	0.786	7.620
S-11	F	49.524	49.336	0.190	0.021	0.006	0.215	0.035	0.046	0.786	7.620
S-11	G	49.436	49.230	0.210	0.021	0.015	0.242	0.062	0.049	0.786	8.687
S-11	H	49.347	49.157	0.190	0.021	0.006	0.217	0.037	0.050	0.786	8.687
S-11	Bent E B-3	49.247	49.057	0.190	0.034		0.224	0.044	0.041	0.786	8.534
S-11	J	49.156	48.959	0.200	0.024	0.009	0.230	0.050	0.047	0.786	7.620
S-11	K	49.036	48.854	0.180	0.024	0.018	0.224	0.044	0.047	0.786	10.668
S-11	Abut E B-2	48.930	48.722	0.210	0.024		0.232	0.052	0.048	0.786	10.668
S-12	Abut E B-1	50.176	49.966	0.210	0.027		0.237	0.057	0.057	0.661	10.668
S-12	A	50.067	49.874	0.200	0.027	0.021	0.241	0.061			
Page Total										5.517	

Figure E-31M: Sample Field Record for Concrete Fill Calculations

If the deck form is built using the offset grade as a reference, the result will be a uniform thickness deck having the required dimension, and the top surface will have a smooth riding surface.

**E605.11 Welding.** Welding is not to be authorized except as designated in the Specifications. Refer to Subsection 605.17 of the Specifications for additional information. **[826.12]**

Prior to the start of erection, the Inspector and Contractor should discuss the requirements for welding as designated in the Plans and Specifications. The discussion should include joint design, welding sequence, electrode types and sizes, and the requirements for inspection by nondestructive testing procedures. Both parties should discuss the importance of the welding sequence and the qualifications of the welders, as welding affects the metallurgical and mechanical properties of the steel.

Prior to the start of welding, the Contractor is required to furnish valid certification that the welders assigned to do the work are qualified to perform the type of welding required.

The Contractor is required to use a clean, dry area for the storage of welding electrodes, wire, and flux. The Contractor is not to be allowed to use electrodes that have been wet. Contractors are to provide certified copies of test reports for the welding electrodes to be used on the Project. The certified copies are to be included in the Project file.

**E605.12 Welding Procedures.** The inspection of the workmanship should include the use of suitable gauges to measure the size, contour, and reinforcement of the welds. A continuous sequence of inspections will enable the Inspector to observe cracks, undercuts, undersize welds, and other problems and have the Contractor immediately correct all deficiencies.

The checklist provided in this Subsection is for the use of Inspectors, and indicates some of the major requirements for inspecting welding:

- (a) Determine the certification of the welders.
- (b) Ensure that electrodes are in conformance with the Specifications and are used correctly.
- (c) Ensure that the condition and capacity of the welding equipment is sufficient for the needs of the Project.
- (d) Check the quality of the welds for overlap, color, porosity, slag inclusion, undercutting, uniformity, and workmanship. The Inspector should ensure that the weld meets the requirements of the welding specifications. **[826.12]**
- (e) Verify that the members fit together tightly. When making fillet welds, the size of the weld is to be increased if the gap exceeds 1/16" (1.5 mm).
- (f) Ensure that the welds are made in sequence to minimize residual stress on the member.
- (g) Ensure that tack welds are satisfactory prior to fusing with final welds. Unsatisfactory welds are to be removed.
- (h) Verify that the materials are clean prior to welding. When doing multiple pass welds, the slag is to be chipped and wire-brushed to a shiny surface prior to the next pass.



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- (i) Do not permit welding to be done in temperatures below 0 °F (-18 °C) or when surfaces are wet from condensation, rain, snow, or ice. The surfaces are to be heated at temperatures between 0 °F and 32 °F (-18 and 0 °C), and the welder is to be properly protected from wind. Material 1½" (38 mm) thick or greater is to be at a minimum temperature of 70 °F (21 °C).
- (j) Ensure that all welds are in conformance with the Plans, including the cross-sectional size, length, location, and omission. Welds are not to be increased arbitrarily, as longer welds may introduce more restraint than calculated.
- (k) Ensure that the operator is welding at frequent intervals and properly operating the equipment. If welding is not being properly accomplished, the Contractor should correct the welder or replace any faulty equipment.

**E605.13 Painting Structural Steel.** Paint received on the Project is to be in sealed containers and is not to be used until the Inspector has received the approval certification from the Materials and Research Section. The certificate is to be filed in the project files. The Inspector is responsible to ensure that the paint to be used is in factory sealed containers with known batch numbers or other means of positive identification. **[605.35]**

If the Inspector has doubts as to the paint being used for structures, a sample is to be obtained and forwarded to the Materials and Research Section for testing. Paint is to be observed for color, viscosity, lapping, and similar characteristics that affect the appearance of the painted surface. **[106.02]**

**E605.14 Painting Inspection Procedures.** During shipment or erection of the structure, certain portions of the shop painting may be damaged. After erection, the damaged areas and the unpainted areas, welded areas, and permanent bolts are to be cleaned in accordance with the Specifications. Immediately after the cleaned surfaces are accepted, the Contractor should paint them with one coat of primer. After the primer has dried, the surfaces will be painted with an intermediate and a finish or top coat of paint. The Contractor is authorized to use only the approved, specified, shop coat paint. **[605.36] [605.37] [605.38]**

The cleaning of the various areas should be inspected prior to application of the paint. It is good practice for the Contractor to start at the top of the structure and paint down. In this manner, any paint drippings can be removed prior to the application of paint. The paint should be applied so as not to show overlapping joints, and all metal is to be covered. The Inspector will inspect the coverage after the first field coat has been applied and is dry. Special equipment is available to the Inspector to measure the thickness of applied paint coatings. Comply with the manufacturer's instructions concerning the time interval to be allowed for drying between the coats of paint. **[605.37]**

An inspection is to be made of the various members of the structure prior to erection for paint damage. Any member that is considered inaccessible after erection should receive a prime coat and two field coats prior to erection. Members normally requiring this type of attention are ends of rail panels, expansion devices, and end floor beams. The Specifications for contracts requiring the painting of steel are explicit. Inspectors should become familiar with the requirements to ensure that the Contractor complies with the Specifications.

**E605.15 Measurement and Payment.** Prior to start of work, the Inspector should review the Plans and Specifications to determine the method of measurement and basis of payment

designated for structural steel. This is necessary to ensure that the Inspector makes all measurements necessary to determine payment for this work. Recoating may be paid for on a per-square-yard (per-square-meter) basis or included in the lump sum price for structural steel. [605.40] [605.41]

**E605.16 References.** The following references should be reviewed for additional information on bridge inspection.

- (a) AASHTO. *Standard Specifications for Highway Bridges, 17<sup>th</sup> edition*. AASHTO: Washington, D.C., 2002.
- (b) FHWA. *Bridge Inspector's Training Manual 90*. Department of Transportation: Washington, D.C., 1995.

## SECTION E606 – METAL BRIDGE RAILING

**E606.01 General.** This work consists of furnishing, fabricating, and erecting aluminum or galvanized steel bridge railing.

Railings and parapets, whether manufactured or job constructed, are to be erected and placed in accordance with the Plans and Specifications. The general alignment and appearance to the public is important. The final alignment should be done by instrument, eye, or a combination of both, with the intent of obtaining the best obtainable alignment.

The Inspector should watch for any rough or sharp corners that may endanger pedestrians and instruct the Contractor grind such areas smooth in accordance with the Specifications. The Inspector must verify that all nuts are tight and bolt threads have been burred. [606.03]

The Inspector should also look for any damage to the coating on the bridge railing. Damaged areas must be touched up by the Contractor. In addition, the surface of the railing must be clean before it can be inspected.

## SECTION E608 – COARSE AGGREGATE FOR FOUNDATION STABILIZATION AND SUBFOUNDATION BACKFILL

**E608.01 General.** This work consists of furnishing and placing coarse aggregate for foundation stabilization and subfoundation backfill.

This work is usually done to level the bottom of a foundation prior to pouring a concrete footing. Coarse aggregate backfill is also used in the bottom of excavations to promote drainage.

**E608.02 Construction Methods.** Unstable foundation material is to be removed and replaced with satisfactory material. If removal cannot be accomplished, the Engineer may approve spreading a layer of sand, gravel or other suitable material on the foundation and working it into the unsatisfactory material until a stable foundation is formed. [608.03]

All pipe culverts are to have the trench bottom cut to a curvature to fit the pipe in accordance with the Standard Construction Details.

## SECTION E612 – REINFORCED CONCRETE PIPE

**E612.01 General.** This work consists of furnishing and installing reinforced concrete round or elliptical pipe. This work also includes the construction of connections to existing drainage inlets and manholes as may be required to complete the work.

**E612.02 Bedding of Pipe.** The Contractor should ensure that the foundation under a pipe is as uniform as possible and will provide firm support to the pipe culvert. The Contractor should be made aware that reinforced concrete pipe (RCP) is not to be placed partly on filled ground and partly on undisturbed ground, because unequal settlement may distort or break the RCP. This requirement applies transversely as well as longitudinally. When the Plans require a hillside location, the RCP is to be benched far enough into the hillside to be entirely on solid ground. If part of the RCP must be on filled ground, the filled material is to be placed in thin layers and thoroughly compacted to provide a foundation as similar as possible to that afforded by undisturbed ground. [612.05] [612.06]

When installing pipe in an embankment, the embankment is to be constructed and compacted to a height of at least 3' (1 m) above the design elevation of the bottom of the RCP. Then, the embankment should be excavated to the proper elevation so that the RCP can be installed.

**E612.03 Laying Pipe.** Manufacturing plants supply RCP per their Quality Assurance Program approved by the Materials and Research Section. The producer should perform a visual inspection and stamp the pipe. The Inspector should inspect RCP upon delivery to the site for damage that may have occurred in transit. Typical types of damage include cracks and broken ends. In addition, the Inspector should ensure that every RCP has the supplier's stamp on it. RCP that arrives on site without the supplier's stamp should be rejected. Video inspection will be required to monitor the placement and condition of the pipe.

The Contractor is to be advised that installation is not authorized on frozen earthwork. The Contractor is responsible to ensure that alignment and grades have been established in accordance with the Plans and Specifications, and that previously approved materials have not been damaged in transit. The Inspector should verify that the Contractor is performing these tasks in accordance with the Specifications. [105.02] [106.01] [106.07]

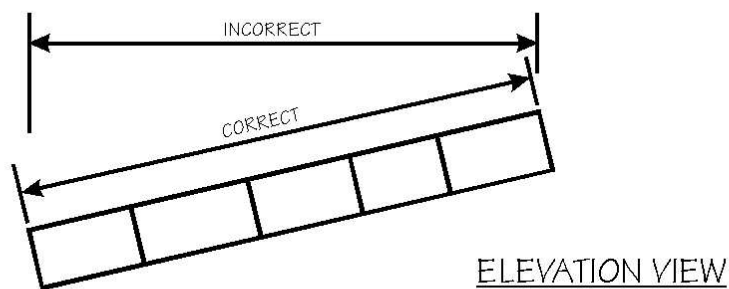
The Contractor must start laying pipe at the downstream end of the pipe with the bell facing upstream unless otherwise approved by the Engineer. Each section of the pipe is to have full contact with the foundation. The joints between pipes will be connected with rubber gaskets. Once the gaskets have been installed, the Contractor must handle the pipes carefully to keep from displacing the gaskets or getting them covered with dirt or other foreign material. The Inspector should ensure that if the gaskets become displaced or damaged, they are removed and either replaced if damaged or repositioned. [612.07] [612.08]

**E612.04 Measurement and Payment.** Figure E-32 illustrates typical pipe installations and a method for measuring for payment purposes. This information does not supersede methods for payment directed by the Specifications. [612.10]

The Inspector should review the Specifications pertaining to when excavation is included in the cost of the pipe and when it is paid separately. [612.11]

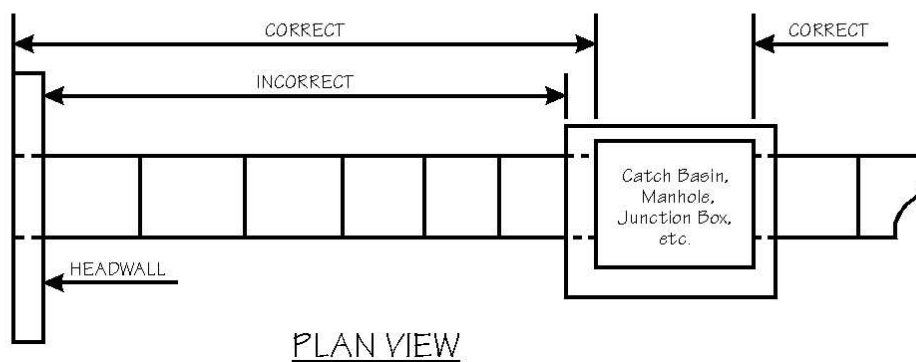
## EXAMPLE

1.



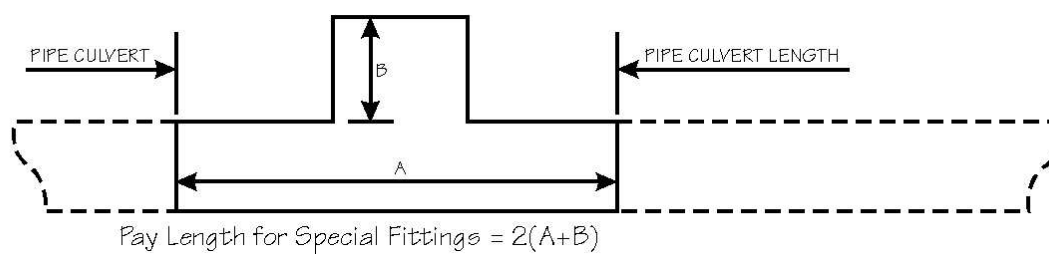
## EXAMPLE

2.



## EXAMPLE

3.

**Figure E-32: Methods for Measuring Pipe Installation**

## SECTION E614 – CORRUGATED PIPE

**E614.01 General.** This work consists of furnishing and installing corrugated steel or corrugated aluminum pipe. This work also includes furnishing and constructing joints and connections to existing pipes, drainage inlets, and endwalls, as may be required to complete the work.

Prior to laying pipe, the Inspector should inspect the pipe for any defects. Subsection 614.05 of the Specifications contains a list of possible defects to be checked. The Inspector should reject defective pipe that cannot be repaired according to Subsection 614.08 of the Specifications. [106.08] [614.05] [614.08]

**E614.02 Pipe Installation.** Corrugated metal pipe culverts should be laid with the separate sections joined firmly together, and the outside laps of joints pointing upstream with the longitudinal laps on the sides. Connecting collars for corrugated metal pipes are to be seated firmly in accordance with the Specifications. The collars, or bands, must include an approved rubber gasket to ensure a watertight seal. [614.04] [614.08]

Additional diameter elongation is not required in the field when Plans require “shop strutting” of pipe. The struts or ties are to conform to the detail required by the Plans. Ties and struts are to be left in place until the embankment is completed and compacted unless otherwise directed by the Engineer. [614.08]

**E614.03 Measurement and Payment.** Refer to the sketches in Subsection E612.04 of this Manual for assistance in measuring pipe culverts. [614.10] [614.11]

## SECTION E619 – INSTALLATION OF PILES

**E619.01 General.** This work consists of installing four types of production and test piles. The four types of piles are timber, cast-in-place concrete, steel H, and precast, prestressed concrete. This work also consists of extracting, removing, and disposing of any test pile where required.

The Inspector should have all Plans, Specifications, and necessary data and supplies in order to perform inspections properly. The Plans and Specifications should be complete with pile types and required bearing capacities indicated, and pile spacing and tip elevations designated on the Plans. The data and supplies needed include inspection forms, the results of the wave equation analysis, and the manufacturer’s specifications for the pile driving equipment. This and other information is described in the following subsections.

**E619.02 Uses of Piles.** A pile is a structural member used to support foundations for structures. One end of a pile, called the pile tip, is driven into the ground and supported by soil and rock. The structure rests on the other end of the pile, called the pile head. Some of the functions of piles in highway construction are:

- (a) To transfer the load of the structure through water or a stratum of low bearing value soil to one of higher bearing value.
- (b) To prevent the possible collapse of structures from scour due to flash floods.
- (c) To anchor structures against uplift or overturning.
- (d) To serve as moorings or anchorages and as dolphins when driven in clusters and wrapped with cable.
- (e) For the construction of groins to protect the seacoast.
- (f) To serve as a fender system to protect a structure’s foundation.

**E619.03 Functions of Bearing Piles.** Bearing piles obtain their capacity to support structures through:

- (a) *End Bearing.* Support is provided to the pile from rock or soil at the tip of the pile. Piles of this type are known as end bearing piles.
- (b) *Friction.* Support is provided to the pile by friction between soil and the lateral surfaces of the pile. Piles of this type are known as friction piles.
- (c) *Combination of end bearing and friction.* From a practical point of view, nearly all piles function as combination piles.

**E619.04 Types of Piles.** Piles may be timber, steel, reinforced concrete or any combination of these materials. The most commonly used piles in Department projects are:

- (a) Treated or untreated timber piles
- (b) Steel shell, cast-in-place, concrete piles. These can be of many types, and may be driven with or without a mandrel as required.
- (c) Steel H piles.
- (d) Prestressed concrete piles.

**E619.05 Character of Loads on Piles.** Three types of forces or loads are considered in a bearing pile:

- (a) *Axial.* Axial loads are considered in both compression and tension. In a batter pile, the axial force has vertical and horizontal components.
- (b) *Shear.*
- (c) *Bending moment.*

The force that the Inspector is most concerned with is the axial force. A pile's capacity to resist an axial force is referred to as bearing capacity, and usually is specified in kips (metric tons). The Department may specify either safe allowable bearing capacity or ultimate bearing capacity on the Plans.

**E619.06 Pile Driving Bearing Capacity Formulas.** Pile formulas are used in the field to estimate the bearing capacity of the pile driven into the soil strata. It is generally recognized that the most dependable method of determining the bearing capacity of a pile is by the application and proper interpretation of a load test. However, pile load tests are very expensive. Therefore, unless it is a large project, pile formulas are used with test piles to determine the pile bearing capacity.

The method used by the Department to determine the bearing capacity of piles is wave equation analysis. Wave equation analysis is performed by using a dynamic model that includes the hammer, cushion, pile, and the soils into which the pile will be driven. The analysis is complex and requires the use of a computer. The results of the analysis include the ultimate bearing capacity, blow count, hammer speed, and driving stress in the pile. The results may be in the form of a table or a table with a graph.

Each analysis is performed based on a given pile length and a given embedment length, which is the distance the pile is driven into the ground. The ultimate capacity is determined from the blow count per foot (meter) or per inch (millimeter). The proper data, with the pile length and embedment length similar to the field condition, must be used. The major advantage of wave equation analysis is that it can determine whether a hammer is capable of driving a pile under the

specified conditions. It can also indicate whether a pile would be damaged or not as a result of the driving stress in the pile. High driving stresses usually are due to over-sized hammers, soft or dense soils, or an improperly positioned pile hammer. Wave equation analysis may specify reduced pile hammer energy if high driving stresses are anticipated.

The safe bearing capacity can be calculated by dividing the ultimate bearing capacity by a safety factor. Unless otherwise specified, the safety factor may be taken as two if there is a pile load test and two and a half if a pile load test is not designated for the Project.

For more details concerning wave equation analysis, refer to the report “Field Manual for WEAP Pile Driving Analysis” by Professor Robert Nichols.

It is important that the type of hammer used in the wave equation analysis is the same type used in the field. Using a different hammer could result in different blow counts and driving stresses than the wave equation analysis calculated, which can affect the bearing capacity of the piles. If the soil conditions in the field differ from those used in the wave equation analysis or the blow counts differ from those calculated, pile driving should be stopped and the Engineer contacted to review the problem.

**E619.07 Test Piles.** Normally, the preliminary driving of one or more test piles is required before driving bearing piles. Several factors are to be considered prior to driving test piles.

The type of hammer the Contractor proposes to use is to be approved in writing by the Engineer. All available boring data is to be studied so that when driving the test pile, the Contractor can anticipate the various conditions to be encountered. When the test is scheduled, the Bridge Engineer will be notified so that he or she may be present. The equipment to be used, the location, and the type of pile to be used are to be approved prior to the Contractor initiating work for driving the test pile. The District Engineer may wish to invite other interested parties to observe the activity. **[619.03] [619.11]**

The Inspector is to ensure that the length of the test pile is marked clearly on the pile in 1' (300-mm) increments. The length should be marked starting at the pile tip so that the length the pile has been driven can easily be determined. For every foot (300 mm) of pile penetration, the blow count is to be recorded. Pile driving forms are to be prepared before the start of work so that the data can be quickly recorded every foot (300 mm) as observed. The data recorded is to be converted to tons (metric tons) of bearing capacity as related to the elevation of the tip of the pile. This will provide an indication of the bearing capacity of the driven pile. Each data sheet is to be titled, dated, and signed by the responsible Inspector. See Part H for a sample of a Test Pile Driving Record.

The pile report forms are to be used by the Inspector whenever continuous driving records are required. The pile report form is to be completed on each pile driven. Should conditions or piles change, pile report forms are to be completed for the new conditions. The Inspector is required to keep records for all piles driven.

The Contractor is responsible for ordering the production piles for the Project. Work is not to proceed until a list has been presented showing the piles that the Contractor believes will produce the bearing capacities as indicated from the test pile results and as required by the Plans and Specifications. The Engineer may exercise the option for approval authority, but when

exercising this option does not obligate the Department to the extent that the order is expected to produce the desired results. The hammer used for all production piles in each footing must be the same hammer that was approved and used for the test piles.

**E619.08 General Notes on Pile Driving.** The Materials and Research Section must test and approve all materials used in the piles. The records of these tests are to be made a part of the Project file. The Inspector should ensure that the piles have not been damaged during shipping. **[106.07]**

The Inspector should check the pile hammer to ensure that it is the same as the one approved by the Engineer. The manufacturer's specifications for the pile hammer should be in the Project files and available for review. These manufacturer's specifications are to be checked against the pile hammer to be used for proper identification and to ensure that the unit conforms to the appropriate Specifications. Refer to Subsection G602.06 of this Manual for additional information. **[619.03] [619.12]**

For steam or air hammers, the power source authorized by the Engineer is to be checked against the manufacturer's specifications to ensure that the proper supply and equipment is on hand. The Inspector is to know the bearing capacity required for each pile to be driven and if a minimum depth of pile penetration is required.

The Inspector is to be familiar with the depth and bearing capacity specified. The Inspector is to know the operating speed to be used for the pile hammer. The same speed must be maintained throughout the operation to produce the energy intended. Please refer to Subsections E619.10 and G602.06 for additional information.

The Contractor is to be made aware that piles such as treated timber, steel, and pre-cast concrete are to be handled with extreme care. When treated timber piles are used, special handling is required to ensure that there is no injury to the surface. Treated or coated piles are to be inspected prior to driving to verify that the protection is still intact. Steel piles are to be handled so that there will be no injury due to bending or denting. Any type of damage to a pile is to be treated in accordance with the Specifications. The method to be used for handling pre-cast piles prior to lifting from the pre-cast beds must be submitted in advance and approved, in writing by the Engineer. **[106.07] [618]**

Prior to the start of pile driving, the Inspector is to check the foundation layout thoroughly to ensure that it conforms to the Plans. All piles, when driven, are to be placed in line and in their true position. The Inspector is responsible to ensure that the Contractor does not deviate from or exceed the requirements of the Specifications as the exact placement of piles is important to the success of the structure. Jetting may be used only with the permission of the Engineer. Jetting is to be kept to a minimum. **[105.02] [619.07] [619.11]**

Depending on the soil conditions, it may become necessary to re-strike either test piles or production piles to verify the bearing capacity. The decision to re-strike will be made by the Engineer. **[619.14]**

When piles are required to penetrate a hard stratum such as embankments, the Contractor may feel augering is required. Augering is allowed only when shown on the Plans or



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approved by the Engineer. Refer to Subsection 619.13 of the Specifications for more information.

The Pile Driving Summary form is designed for recording the vital statistics derived from the pile driving operations on the entire Project. It does not contain foot by foot (meter by meter) driving records. The Pile Driving Summary form is to be used in conjunction with the individual test pile records. See Part H for a sample Pile Driving Summary form.

**E619.09 Selection of Pile Hammer.** Using a type of pile hammer that is not appropriate for the driving conditions may result in a large loss of kinetic energy during compression and impact. This could result in the actual bearing value being different from the assumed bearing value. Generally, the pile hammer used should be the heaviest hammer that can safely be used without damaging the pile. When driving piles, if the Inspector thinks a pile is being damaged, the pile may be withdrawn for examination. [105.02] [619.12]

Generally, more energy is imparted to the pile when the selection results in a heavy blow with a heavy ram and a short stroke at a low velocity. The selection of the driving hammer is the responsibility of the Contractor, but written approval of the Engineer is required. [619.03]

For more information on pile hammers, see Section G602.

**E619.10 Driving Procedures.** The purpose of pile driving equipment is to hold the pile in a fixed position and drive it to the required depth at the required angle. The pile-driving rig should be stable and heavy enough to support both the pile and the hammer without obvious movement or sway during driving. The leads should be as long as required to handle and drive the pile in one piece. Driving piles in short pieces could result in piles that are not straight and are of questionable capacity. Driving is not to be authorized when the pile can not be driven in one piece without prior permission from the Engineer. Leads should be used that adequately support and guide the pile during driving. Refer to Subsection E619.09 for hammer selection. Refer to Section G602 for types of hammers. [619.03] [619.04] [619.05] [619.06]

Driving should be continuous whenever possible. When driving through cohesive soils, pore water pressure builds up. This loosens the soil, which may result in lower than expected blow counts. The pore water pressure dissipates when driving stops, causing the soil in the area of the driving to “tighten up.” This increases the resistance on the pile, resulting in higher blow counts. If pile driving is interrupted and this “tightening up” occurs, it falsely indicates on the driving record that the pile is approaching the required bearing capacity. When pile driving is interrupted, the driving record for that pile should be noted accordingly so that the data is not misinterpreted to indicate a hard driving spot for the pile.

Sometimes, blow counts will be much lower than expected as the pile tip approaches the estimated elevation due to the build up of pore water pressure. If this occurs, the Engineer may direct the Contractor to interrupt driving, typically for 48 hours. This will allow the pore water pressure to dissipate, and will result in a more accurate reading of the bearing capacity of the pile.

The tops of piles are to be cut to the final cut-off elevation shown on the Plans. After cut-off, the tops of timber piles are to be treated in accordance with the Specifications. [619.16]

The Inspector is to examine steel shell piles after driving to ensure that they are not dented, bent, or damaged in any manner. The Inspector should also determine if there is water or other material at the bottom of the steel shell pile. If any water or foreign material is found, it is to be removed as soon as possible. A suggested method of examination is to reflect sunlight off a

mirror. The reflected light is cast to the pile tip so that the entire inside of the pile may be examined. If filling with concrete is not accomplished immediately, the pile shells are to be carefully covered and kept covered until ready for the fill. When casting is delayed, the shells are to be re-examined just prior to the placement of concrete. **[619.18]**

The Specifications are to be followed when driving cast-in-place concrete piles concerning when the piles may be filled and when driving may be resumed in the immediate area. Driving records are to be carefully recorded on forms provided by the Department and transferred to the Estimate Book. See Part H for a sample Pile Driving Record. A record should be kept for every pile, including the number of blows per foot (300 mm) for every pile. One of the reasons for maintaining records is that anything may happen to the pile or to the driving equipment or something unexpected may be encountered during driving. The Inspector would find it difficult to go back and attempt to reconstruct a driving record. Regardless of the circumstances, it is necessary that a continuous record be kept.



**Figure E-33: Setting a Pile prior to Driving**

**E619.11 Batter Piles.** Batter piles are to be driven in accordance with the Plans and Specifications. The intended batter angle should be maintained during driving. To maintain proper alignment and to minimize the chance of pile damage, driving batter piles should be done with a template. Friction within the hammer or leads affects all hammers to some degree. The stroke length is affected slightly in single-acting hammers, and, accordingly, the theoretical stroke length is adjusted slightly. Double-acting and differential-acting hammers will automatically compensate for losses due to driving piles on a batter by a slight reduction in speed with the resultant reduction in energy, which will be automatically compensated for when the hammer speed is recorded. [619.05]

**E619.12 Cast-in-place Concrete Piles.** Cast-in-place concrete piles are to be filled in accordance with the Specifications. Concrete is not to be placed until the pile shell has been approved and all water and other foreign debris has been removed. Concrete for each pile should be placed in a continuous operation. The only exception to this requirement is when steel reinforcement is not designed to extend for the full length of the pile. In this case, the reinforcement should not be placed until the concrete being placed reaches the elevation of the lowest end of the reinforcement. The reinforcement should then be rigidly set in the pile casing, and the concrete placement should be continued. The pile is not to be disturbed for at least three days or as otherwise specified. [619.17] [619.18]

Concrete is not to be placed in the piles unless all piles within a 15' (5 m) radius have been driven. If this procedure cannot be followed, pile driving within the prescribed radius is not to be permitted until the concrete placed in the last pile has been allowed to cure for seven days. [619.18]

**E619.13 Inspector's Checklist for Pile Driving.** The checklist provided in this Subsection is for the use of inspectors, and indicates some of the major requirements for inspecting pile driving: [619]

- (a) Become familiar with the Plans and Specifications for the piles on the Project.
- (b) Determine the pile details, bearing capacity, and minimum tip elevation from the Plans and Specifications.
- (c) Check the steam or compressor capacity against the pile hammer manufacturer's rating. Refer to Subsection G602.06 for more information.
- (d) Check the condition, size, and length of pile shells before driving.
- (e) Check the type of pile hammer and the size, weight of the ram, energy per blow, and rated strokes per minute.
- (f) Ensure that the pile and mandrel are plumb before driving.
- (g) Check the lateral tolerance of the pile position.
- (h) Ensure that the pile is properly aligned during driving.
- (i) Review boring data to ensure that the ends of piles are in solid material and that there is no compressible soil stratum below.
- (j) Inspect the condition of the pile shell and ensure that it is clean just prior to filling with concrete.
- (k) Ensure that only concrete that meets the Specifications is used to fill pile shells and that the concrete is protected against freezing during pouring and curing.
- (l) Ensure that all driven piles are cut off at the proper elevation.

- (m) Treat the heads of timber bearing piles properly, and be certain that no untreated pile heads project above the water line.
- (n) Check the adjacent areas for possible damage due to pile driving.
- (o) Ensure that timber piles are at a safe bearing value. The following tables give safe bearing values for timber piles driven with hammers of different sizes. These tables can be used as a guideline to ensure that timber piles are within their allowable safe bearing values.
- (p) Ensure that, after driving, prestressed concrete piles shall have their tops covered with plastic to prevent dirt and water from entering the holes/sleeves provided for grouting in bar reinforcement for anchorage into the pier caps or the abutment footings. Prior to grouting in bar reinforcement, such holes/sleeves shall be blasted out with air to remove any dirt and/or water.

**E619.14 Measurement and Payment.** Payment for piles is in two Specification Sections: pile materials are covered in Section 618 and installation of piles is covered in Section 619. Pile materials are measured in linear feet (linear meters) and the total length ordered is paid for as specified in Section 618 of the Specifications. Installation of piles is also paid by the linear foot (linear meter) but for only the amount of the pile actually driven from tip elevation to cut off elevation. Pile build-ups constructed will be measured and paid as pile material, not as installation of piles, since a pile build-up is not driven but is constructed. Material used to construct pile splices will be measured and paid as pile material. Due to the difficulty in splicing precast, prestressed concrete piles, the Contractor will be compensated for labor as specified in Subsection 619.20 of the Specifications. This pile type is the only one where the Department compensates the Contractor for the additional labor required to splice the pile.

**E619.15 References.** The following manual should be reviewed for additional information on pile installation:

NAVFAC. *Foundations and Earth Structures, Design Manual 7.2*. Naval Facilities Engineering Command, Department of the Navy: Alexandria, VA, Sept 1986.

## SECTION E621 – TIMBER SHEET PILES

**E621.01 General.** This work consists of furnishing and placing either untreated timber sheet piles or creosoted timber sheet piles. [621]

Sheet piles or sheeting may be used for many purposes, such as to prevent scouring under structures, to protect a riverbank, or to provide a bulkhead. They may be of treated or untreated timber.

**E621.02 Timber Sheet Pile Inspection.** The checklist below is for the use of Inspectors, and indicates some of the major requirements for inspecting timber sheet piles:

- (a) Timber sheet piles should be inspected to see that they are in conformance with the Plans and Specifications.
- (b) Timber sheet piles are to be driven, or jetted if permitted, to the required depth, and should be placed so that they are tight, plumb, and well secured. A position template should always be used during driving.

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- (c) No unreasonable creep from the vertical position should be permitted. If any sheet pile should creep, corrections are to be made as directed by the Engineer.
- (d) Any damaged surface treatment must be repaired by the Contractor before driving.

## SECTION E622 – PERMANENT STEEL SHEET PILES

**E622.01 General.** This work consists of furnishing and placing untreated steel sheet piles. [622]

**E622.02 Driving Steel Sheet Piles.** Driving conditions may vary considerably according to ground conditions and the type of sheet pile structure. The following basic principles are to be considered:

- (a) *Drive Pairs of Piles.* It is usually more economical, and less resistance is found, when piles are driven individually. However, pairs of piles are easier to guide and present the most desirable impact area to the pile hammer.
- (b) *Drive in Stages.* This depends on the density of the soil and underground obstacles. Driving in stages allows each pile to be guided by its neighbor. A rule of thumb suggests that no sheet pile be driven more than one-third its length before the adjacent sheet pile is driven.
- (c) *Prepare for Obstructions.* If borings or other information show obstructions, sheet piling should be driven in panels. When an obstacle is hit, stop driving and move the hammer to the next pile to be driven. With piles on both sides of the obstacle acting as guides, it is often possible to drive through the obstacle. Increasing the number of hammer blows helps to drive piles through obstacles.
- (d) *Plug the Open Interlock.* Material can be prevented from clogging the open interlock by forcing an object shaped similarly to the interlock into the open case of the leading interlock.
- (e) *Check the Pile Walk.* If a closure is required, marks should be placed on the template to check the walk, or excessive advance, of the sheet piling. Wedging the pile against the guide and pulling on the guide with cables will help reduce the chance piles will walk out of alignment.
- (f) *Prevent Leaning.* A wall of sheet piling will tend to lean in the direction of driving. This is due to slack in the interlocks and improper hammering and guiding. Leaning must be corrected as soon as discovered. Leaning may be corrected by pulling back the top of the last driven pile with a cable, or by sloping the line action of the hammer towards the driven section of the wall. Another method is to set a panel, then drive the first and last pairs of piles about halfway to serve as master piles. Intermediate piles are then driven to the same depth. The master piles are then driven to their final depth, followed by the intermediate piles.
- (g) *Do Not Overdrive.* At times, a driven pile may be drawn down by the next pile being driven if the ground is very soft, or where high frictional forces develop in the interlock. Pile draw down may be prevented by bolting or wedging driven piles to their wales. Should draw down occur before precautions are taken, it is usually better to lengthen the pile drawn down than to try to lift it.

- (h) *Plan Driving Based on the Soil.* A rapid succession of hammer blows is more effective in sand and gravel. Slower and heavier blows are best in clay.
- (i) *Paint Marks.* Paint marks are to be placed every 12" for 36" (300 mm for 1000 mm) from the top of each pile before driving to provide a check on the amount burned off from the top by battering.
- (j) Lift holes in the top of the sheet piles must be filled after driving unless they are within the area covered by a concrete cap.
- (k) *Use Multiple Hammers.* Driving often may be speeded by first tacking piles into the ground with a light hammer, then finishing with a heavier one.

**SECTION E623 – PRESTRESSED REINFORCED CONCRETE MEMBERS**

**E623.01 General.** This work consists of furnishing and erecting prestressed, precast, reinforced concrete members and accessories, on substructure units. This work also includes furnishing and installing bearing pads and materials, dowels, tie rods, nuts, plates, joints and joint materials, scuppers, and all other parts and materials required to complete the work.

Prestressed reinforced concrete is concrete that is cast at a manufacturing plant using cables that are placed in tension before the concrete is poured. After the concrete has cured, the tension is released from the cables. Prestressed concrete has a higher compressive strength than conventional concrete with the same mix design.

Construction inspection of the prestressed members is usually done by a commercial testing laboratory. Evidence of inspections should be on record in the Inspector's Project files indicating that satisfactory inspection of the construction has been accomplished. The Inspector should be aware that the handling of the prestressed members from time of arrival to the time of erection is a critical issue. The prestressed members are to always be kept in an upright position and lifted from a two-point position. Lifting is to be made only at the proposed points of support. The prestressed members should never be placed on the ground so that they will bear weight at any point except at the two lift points. [623.16] [623.17]



**Figure E-34: Placing a Prestressed Reinforced Concrete Beam**

The Specifications describe the erection and completion of this type of member when it is used in a bridge. The prestressed members should be fitted tightly, carefully, and centered. The joints should be filled in accordance with the Specifications so that they will remain tight and waterproof. The areas on which they will bear should be prepared carefully at the elevations and plane specified. Bearing pads are to be provided as specified and placed properly. Prestressed



members are to be examined closely for any handling or shipping damage or manufacturing imperfections. [623.17] [623.18]

The following checklist should be used by the Inspector when building with prestressed reinforced concrete members:

- (a) Check for cracks. Small cracks are usually due to shrinkage and not critical to concrete strength; however, large cracks indicate that the members were mishandled.
- (b) Look for members that have pieces of concrete broken off. This usually indicates that the member was dropped or had something dropped on it.
- (c) Check the reinforcing steel that sticks out of the members. If the steel is broken or bent, then it will be difficult to attach the member to other bridge members, which may impact overall bridge strength.
- (d) Make sure that prestressed beams are stored in an upright position until use and do not tip over. If the beams are stored upside down, or tip over, they will crack.
- (e) Check and record girder camber when the members arrive on the Project site and again after placement. If the camber is not as shown on the Plans, inform the Bridge Section immediately.
- (e) Verify that the members are being stored off the ground, and that the supports for the members are placed where the actual structure supports will be located.

## **DIVISION E700 – MISCELLANEOUS CONSTRUCTION**

### **SECTION E701 – CURB AND INTEGRAL CURB AND GUTTER**

**E701.01 General.** This work consists of constructing portland cement concrete curb and integral curb and gutter.

The locations where curb and integral curb and gutter will be constructed are to be staked and checked before the work begins. Offsets noted on the Plans or radius distances given normally reference the bottom of the vertical face of the curb.

**E701.02 Foundation.** Normally curb and integral curb and gutter are constructed on a graded aggregate base course material or a soil foundation that has been compacted to meet the requirements of the Specifications. Sometimes, however, curb and integral curb and gutter may be constructed on existing undisturbed soil. In such cases, all unsuitable material must be removed and replaced with suitable material. Compaction and density requirements for replacement soil are provided in Section 209 of the Specifications. [701.05]

**E701.03 Fixed Forms.** When constructing curb and integral curb and gutter using fixed forms, the forms are to be straight and strongly constructed and braced to ensure that the proper alignment and grade are maintained. [701.06]

**E701.04 Slip Forming.** When constructing curb and integral curb and gutter by slip forming, the following should be checked:

- (a) The paver elevations should be set so that the curb will be constructed to the dimensions required by the Plans.
- (b) The stringline should be checked for proper grade and alignment.



- (c) The space between contraction joints should be in accordance with the Specifications. [701.03] [701.07]
- (d) Expansion joints should be constructed as required by the Specifications. [701.03] [701.07]
- (e) Joints should be saw cut to the proper depth and width. [701.07]

**E701.05 Placing Concrete.** Prior to placing concrete, the base course material is to be thoroughly moistened so that it will not absorb an excessive amount of moisture from the fresh concrete. [701.08] The limitations on placing concrete in hot or cold weather apply to this work, and the Inspector should ensure that these requirements are followed. [701.08] [501.04]

**E701.06 Joints.** Joint spacing, joint material, and reinforcing steel, if required, are shown on the Plans or stated in the applicable Specifications. [701.03] [701.04] [701.07] [701.09] [701.10]

**E701.07 Finishing and Curing.** The Contractor is to finish and edge the curb and gutter in accordance with the Specifications. Normally the Contractor has a choice of several methods for curing the concrete. Once a method for curing is approved, only that method is to be used to obtain a consistent appearance. [701.11] [701.12] [701.13]

**E701.08 Backfilling.** Backfilling of curb and integral curb and gutter is to be accomplished as soon as possible and in accordance with the Specifications. [701.14]

**E701.09 Protection of the Work.** At times during the construction and curing work, bridges for pedestrians or vehicles may be required for the protection of the work.

The Contractor is to be made aware that when constructing sidewalks adjacent to curbs or integral curbs and gutters, care is to be taken that the curb is not damaged or discolored.

**E701.10 Measurement and Payment.** The Inspector should note that curb and integral curb and gutter are measured by the linear foot (linear meter) along the front face of the finished curb. The Inspector should also note what elements of work are included in the price for this Contract Item.

Source document drawings are not normally needed for curb or curb and gutter. Instead, the Inspector should list on the source document the exact location and beginning and ending station with offset from centerline, as well as the measurement of each separate run of curb. For curb placement within subdivisions or on projects without a baseline reference, a house number or street address should be used to note the location of the curb.

## **SECTION E708 – DRAINAGE INLETS AND MANHOLES**

**E708.01 General.** This work consists of constructing reinforced portland cement concrete drainage inlets and manholes.

Prior to the Contractor starting to work on drainage inlets and manholes, the Inspector should become familiar with the planned and existing drainage conditions to ensure that the drainage structures are properly located. To ensure that drainage inlets are built at the proper location, accurate survey layout is essential, with a minimum of two offset stakes per inlet. Refer to Section E812 of this Manual for information concerning concrete requirements.

**E708.02 Foundation.** The Inspector should ensure that the soil foundation meets the requirements of the Specifications prior to the start of construction of the drainage inlet or manhole floor. The foundation material is to be firm and dry to properly support the furnished structure. If it is difficult to obtain a firm and dry foundation, it is recommended that the Contractor place 8" (200 mm) of graded aggregate for foundation stabilization. [708.08]

**E708.03 Reinforced Concrete Construction.** Drainage structures constructed in place are to be constructed of reinforced concrete. The walls of the drainage structures are to be constructed plumb and the dimensions of the structure are to be in conformance with the Plans. [708.02] [708.09]

**E708.04 Precast Drainage Inlets and Manholes.** If precast or prefabricated units are used, all the joints are to be sealed to ensure that they are watertight. The Inspector should ensure that the Contractor fills the annular space of joints between precast sections with a joint sealant meeting the requirements of AASHTO M 198. [708.10]

**E708.05 Castings and Gratings.** Castings and gratings used on top of drainage inlets and manholes should be inspected for possible defects and proper fit. [708.05] [708.06] Castings should be randomly weighed to ensure that they meet the weight requirements of the Specifications. Frames for castings are to be carefully adjusted to the line and elevation shown on the Plans and set in a full bed of mortar. [708.11]

**E708.06 Backfill.** Refer to Subsection E208.03 for information concerning the backfilling operation. Particular attention must be given under and around pipes within the excavated area of the structure. [708.14]

## SECTION E713 – GEOTEXTILES

**E713.01 General.** Geotextiles are fabric barriers manufactured from polymeric materials. These products are placed between dissimilar materials, such as soil, rock, and earth, so that the integrity of both materials can remain intact. The primary uses of geotextiles are stabilization, separation, and filtration.

**E713.02 Delivery and Storage.** Geotextiles are delivered in rolls covered with a protective wrapping. Labels on the outside of the wrapping of each roll identify the manufacturer, style name, roll number, lot or batch number, and the roll dimensions. The Inspector will verify that the material delivered to and used on the project conforms to the Specifications [713]. Make sure that the Contractor maintains the protective wrapping during shipment and storage, and elevates the geotextile off of the ground during storage to protect from:

- (a) site construction damage;
- (b) precipitation;
- (c) immersion in ponded water
- (d) ultraviolet radiation, including sunlight;
- (e) chemicals, especially strong acids or bases;
- (f) flames, including welding sparks;

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- (g) temperatures in excess of 160 °F (71 °C); and
- (h) any environmental condition that may damage the physical properties of the geotextile.

**E713.03 Construction.** The protective wrapping must not be removed from the geotextile roll prior to placement. If the Contractor intends to leave geotextiles unrolled without their protective covering for more than 14 days, then direct the Contractor to take measures to ensure no damage or degradation occurs to the material. If damage does occur, the damaged section must be replaced prior to final incorporation into the project. Any patches or repairs must comply with the manufacturer's recommendations. Patches must extend at least 3' (1 m) beyond the edge of the damaged area. Seaming geotextile materials must be done in accordance with the Plans and Specifications. The seaming procedure may involve the use of adhesive compounds, welding by hot air or torch, or sewing. Sewing is accomplished using specialized equipment approved by the manufacturer. In some cases it may be sufficient to overlap geotextile materials. If the Engineer approves overlapping, a minimum overlap distance will be specified.

**E713.04 Measurement and Payment.** Measurement and payment for geotextile installed will be on a unit price basis as provided in Section 713.06 and 713.07 of the Specifications.

## SECTION E715 – PERFORATED PIPE UNDERDRAINS

**E715.01 General.** This work consists of constructing perforated pipe underdrains.

Perforated pipe underdrains usually are placed to dispose of water seeping into the roadbed from sources outside of the roadbed and the back slope. Perforated pipe underdrains are installed in a trench wrapped in a geotextile fabric and backfilled with stone to aid in drainage. The locations of underdrains are normally determined by soils investigations performed prior to the completion of the Plans or during grading operations. Changes in the design location or the selection of additional locations should be made by the Engineer after consulting with the Materials and Research Section, and should be documented in writing by the Engineer.

**E715.02 Construction Methods.** Perforated pipe underdrains are to be installed with the perforations facing downward. Close observation is required during the construction of perforated pipe underdrains. Although means and methods of construction are determined by the Contractor, the Contractor should generally install perforated pipe underdrains according to the following sequence of operations:

- (a) Excavate the trench to the grade shown on the Plans.
- (b) Lay filter fabric into the trench.
- (c) Place stone to the specified depth on top of the filter fabric within the trench.
- (d) Lay the perforated pipe.
- (e) Cover the pipe with stone as shown on the Plans and Standard Details, making sure the proper grade is maintained.
- (f) Fold the filter fabric over the top of the stone as shown on the Plans and Standard Construction Details.

The Inspector should check that the filter fabric is not cut or torn and that it is properly lapped. The Inspector should also ensure that the pipe is set to drain properly.

The Contractor should be alert to material sliding from the sides of the trench into the trench bed. Any materials that slide into the trench bed should be removed to ensure that the granular backfill does not mix with other materials and that no dirt covers the underdrain when granular or porous base course material is used. The Contractor should also ensure that the holes in the perforated pipe underdrain are not clogged with foreign material, which would prevent the underdrain from functioning properly. Prior to paving, if equipment must cross perforated pipe underdrains after installation, the Contractor should place a rigid cover over the trenches to protect the pipe from being crushed and the granular material from being contaminated. [715.06] [715.07]

**E715.03 Video Inspection.** To ensure that the underdrain pipe has not been damaged during construction, the Contractor is required to have the system inspected by a video camera prior to final inspection. Refer to Subsection 715.07 of the Specifications for more information.

## **SECTION E720 – GALVANIZED STEEL BEAM GUARDRAIL**

**E720.01 General.** This work consists of constructing galvanized steel beam guardrail and guardrail end treatments.

The locations of the stakes for the galvanized steel beam guardrail should be reviewed to ensure that the guardrail will be properly placed to prevent a vehicle from running behind the guardrail into a hazard. All changes are to be approved by the Engineer. All new guardrail and guardrail end treatment installations must be with hardware that has passed NCHRP 350 Test Level 3 criteria.

**E720.02 Site Grading.** The Inspector is to ensure that proper grading is performed in front of, behind and in advance of guardrail and guardrail end treatments. Proper grading requirements can be obtained from the Standard Construction Details and the manufacturer's literature. Adequate soil support is necessary for the post to prevent it from pushing backwards too easily. If at least 1' (300 mm) of soil support, no steeper than 4:1, cannot be provided, extra long posts, 7' to 8' (2.1 m to 2.4 m), need to be used in place of standard length posts.

**E720.03 Construction Methods.** If the pavement is not in place when galvanized steel beam guardrail is constructed, the pavement centerline is to be established so the guardrail posts can be aligned. Posts are to be set plumb, spaced as shown on the Plans, and the top of the posts set to the design elevation. Normally, steel posts are driven into the ground and the holes for wood posts are auger dug. After the wood posts have been placed in the auger-dug holes, they are to be immediately backfilled, compacted, and completed as stated in the Specifications. The rail laps are to be placed in the direction of vehicular travel. The Inspector is to ensure that the guardrail has the proper alignment both vertically and horizontally. Guardrail height is measured as follows:

- (a) The guardrail height is measured from the ground directly beneath the rail if grading is 10:1 or flatter.
- (b) The guardrail height is measured from the shoulder slope extended if grading is steeper than 10:1 but no steeper than 6:1 and the face of rail is within 2' (600 mm) of the shoulder/frontslope hinge point.

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- (c) If grading is steeper than 10:1 but no steeper than 6:1, guardrail is not recommended in the area greater than 2' (600 mm) and less than 12' (3600 mm) from the shoulder/frontslope hinge point.
- (d) The guardrail height is measured from the ground directly below the rail if the face of rail is greater than 12' (3600 mm) from the shoulder/frontslope hinge point.
- (e) No guardrail is to be placed on slopes steeper than 6:1.

Adequate deflection distance must be provided between the back of guardrail system and any rigid object. The flare rate must not exceed allowable criteria (about 12:1) and can only be over slopes 10:1 or flatter. A detailed discussion of guardrail installation is provided in Chapter 5 of the AASHTO Roadside Design Guide. The Inspector should verify that the Contractor has called Miss Utility prior to driving posts.

To check for satisfactory Length of Need (LON) on high-speed roadways, determine the distance (D) from the edge of traveled way to the far side back of hazard (maximum value of 30' [9 m]). Walk upstream along the edge of traveled way a distance of 15 x D, beginning at upstream side of hazard. Sight from this position to the upstream face, back edge of hazard (maximum value of 30' [9 m]) and the end treatment of guardrail run should be close (within approximately 20' [6 m] either side) to the line of sight. For low-speed roadways use a distance of 8 x D. The Inspector should notify the Area Engineer/Construction Manager of any locations perceived to have inadequate lengths of guardrail prior to making any adjustments to the planned installation.

The Inspector should ensure that the Contractor repair any damage that occurs to the galvanizing during post installation. The Inspector should check whether the driving of guardrail posts has cracked the bituminous pavement. If any pavement is cracked, the Inspector should ensure that the Contractor repairs the pavements. **[720.03]** The Inspector should also check to ensure that reflectorized washers are installed properly. **[720.03]**

The methods to terminate guardrail, in order of desirability when site conditions allow, are buried in back slope end treatments, flared end treatments and parallel end treatments. Flared end treatments are only to be used if there is a large clear runout area (about 250' [75 m] for high speed roadways) downstream and behind the guardrail and there is full standard grading. The Inspector is to obtain approved shop drawings to verify proper installation of guardrail end treatments. All wood blocks on wood posts are to be toe-nailed to the post – one nail each side. The anchorage cable should be taut, which means that the cable can not be easily lifted more than 1" (25 mm). When tightening the nut to make the cable taut, the cable must be restrained from twisting. This can be accomplished by clamping the cable with a wrench while the nut is being turned.

**E720.04 Measurement and Payment.** The Inspector is to measure and record the accepted lengths and locations of the guardrail sections and guardrail end treatments and verify that the required tests and certificates of compliance are placed in the Project files. Guardrail sections within the limits of payment for guardrail end anchorages, buried end sections, attenuators, guardrail over culverts, guardrail to barrier connections and bridge rail retrofits are incidental to the associated items and should not be paid under the guardrail item.

## SECTION E727 – FENCES AND GATES

**E727.01 General.** This work consists of furnishing and erecting chain-link and right-of-way fence and gates, and resetting and repairing chain-link fence.

**E727.02 Materials.** All the materials used to construct fences and gates, woven wire fabric, barbed wire, chain link fabric, posts, braces, and miscellaneous hardware must be in conformance with Subsection 727.02 of the Specifications.

**E727.03 Construction Methods.** The proposed locations as shown on the Plans are to be reviewed prior to the start of work. The Contractor should be encouraged to arrange for all locations to be staked in advance of the work. If, after staking out the proposed fence locations, it appears to the Inspector that the fence should be relocated, then the Inspector should coordinate the proposed relocation with the Engineer and the Contractor.

The Inspector is to inspect the installation or erection of all posts to ensure that they are erected true to line. The Inspector is to ensure that the wire fabric and the required hardware are attached to the posts in accordance with the Specifications and as shown on the Standard Details. The Inspector should also check that posts are firmly installed, are at the proper elevation, and that the fabric is installed on the specified side of the posts and at the correct height above the ground. [727.09] [727.11]

**E727.04 Measurement and Payment.** The Inspector is required to measure and record the accepted quantity for the types of fences and gates installed. Subsection 727.14 in the Specifications should be consulted for detailed instructions on how to measure fences and gates. The Inspector should also review the basis of payment requirements in Subsection 727.15 of the Specifications to understand what elements of work are included in the Contract Unit Prices for fences and gates. [727.14]

## SECTION E732 – TOPSOIL

**E732.01 General.** This work consists of furnishing and placing topsoil for planting.

**E732.02 Preparation of Subgrades.** A layer of newly placed topsoil may erode if not properly bonded with the subsoil underneath the new layer. This usually occurs because the roots of grass do not penetrate the lower, different layer of soil. Scarification of the subsoil, which may leave 3 to 4" (75 to 100 mm) furrows and ridges, before topsoil is placed is important to avoid erosion of the topsoil.

**E732.03 Handling and Placing Topsoil.** Topsoil should not be handled when it is very wet, as it will become densely compacted during placement. A quick way to determine if topsoil is too wet is to form a handful into a ball and see if it holds its shape. When placing topsoil, the Inspector should check the material to ensure that there is no change in the kind or source of the material. Some common indicators of changes in material are changes in color, texture, or moisture content of the topsoil. Finished surfaces of all areas where topsoil is placed are to be in a condition to permit seeding immediately. Refer to Section 734 of the Specifications for the requirements for seedbeds. [732.03] [732.06]

## SECTION E734 – SEEDING

**E734.01 General.** This work consists of furnishing and placing seed and soil supplements.

**E734.02 Seeding Season.** When seeding dates are specified, serious consideration is to be given to the extension of the seeding dates, as they may be critical, particularly when no mulching is called for. When extensions are authorized, they should include the provisions of mulching or watering. The permission to extend a seeding date is to be authorized in writing by the Engineer after verification from the Roadside Management Section. If the Engineer authorizes an extension of the seeding dates, the Inspector should ensure that the Contractor complies with the mulching, watering, and guarantee provisions included in the extension authorization.

The Engineer can stop seeding work whenever the climate or soil conditions are unfavorable. The Engineer should be notified if the Inspector feels that unfavorable conditions exist. Conditions to watch for include ground that is frozen, too wet, or too dry. Seed and fertilizer may wash away on frozen ground. Seeding is not to take place when wet soil sticks to a roller or when drought results in dry surface soil. In the case of drought conditions, the Contractor should delay the seeding operations until sufficient rain has fallen. [734.06]

**E734.03 Receiving and Storing Materials.** The Contractor is responsible for ordering materials and providing proper storage facilities free from moisture, heat, and rodents. The Inspector is to ensure that the numbers and weights of bags of seed, fertilizer, and lime actually used are a part of the record for approving payment for the areas completed. The count provided by the Inspector should be of material used, not material delivered to the Project. [106.07] [734.04]

**E734.04 Seed Material Approval.** The Inspector is to review the labels from the sealed bags or containers to ensure that the seed furnished is in accordance with the Specifications. Certification for the seed must be on file with the Materials and Research Section prior to use. Questions concerning the delivered seed may be referred to the Roadside Environmental Supervisor. [106.02] [734.04]

**E734.05 Seedbed Preparation.** Irregularities of the surface that would pond water should be eliminated, as good drainage is essential to the successful growth of grass.

- (a) *Scarification.* Soil will sometimes develop a hardened layer of crust on its surface. Normally, sand will not crust unless it is exposed and undisturbed for an extended period. However, soil with a high silt or clay content has a tendency to crust over following a light rain shower. This surface crust is a detriment to effective seeding. It is important for the surface crust to be broken up before seed is placed on soil that is not tilled or mulched, or where the seed is not covered by soil.
- (b) *Tilling.* The soil in areas to be seeded is to be loosened to a depth of 6" (150 mm) prior to seeding. A common method for loosening the soil is to till it. A rotary tiller is generally efficient and gives satisfactory results in one pass on sandy soils. Contractors may also use other equipment, such as a disc harrow, spike tooth harrow, chisel plow, tracking, or spring tooth harrow. The extent of loosening may vary with the kind of soil, the condition of the soil during the operation, equipment used to loosen the soil, and other factors that may have affected the soil after placement. [734.07] [734.08]

When the soil is wet enough to cling to the equipment, such as a disc harrow, or the ground is frozen, preparation for seeding is not to be attempted. The reason for this is that the soil is not being broken down into the fine particles necessary for seed coverage. The Contractor may wish to use equipment such as a rotary tiller to dry the soil if it is necessary to expedite completion of the work. This type of operation is permitted, but may be expensive for the Contractor. If the Contractor chooses to try to dry the soil, seeding is not permitted to occur until the Engineer approves the soil conditions. If tilling operations are followed by a heavy rain, it may be necessary to break the surface crust just prior to seeding. Prior to allowing the Contractor to seed, the Inspector must measure the area to be seeded and calculate the amount of seed needed for the area measured using the Standard Form in Part H. Both the Contractor and Inspector should agree upon the quantities prior to mixing. The Inspector is to witness and verify that the Contractor mixes the correct amount of seed for the specific location. [734.06] [734.07] [734.08]

**E734.06 Seeding.** The rate of seeding should be checked at the beginning of the work and frequently during the course of the operation. This is normally done by measuring the area seeded with a measured quantity of seed. The Inspector should verify that the Contractor has ensured the seed is thoroughly mixed or constantly agitated during seeding to prevent the heavier seed from settling on the bottom of the distribution tank. Broadcast seeding is not to be done when there is a possibility of wind blowing the seed into an irregular pattern. The Inspector must check the tank to ensure that all the seed mix was used. [734.03] [734.07] [734.08]

Slit seeders may be used for seeding regardless of the winds. The Contractor should be aware that when slit seeding is used, the seed might be placed too deep. Mechanical seeders should produce a satisfactory coverage when operated in one direction only. When seeding is done by hand or with a mechanical hand seeder such as a cyclone, seeding should be done in two directions at right angles from each other.

When raking is employed, it should be accomplished so that the depth of the seed is preserved and an even pattern of seed distribution is maintained. Rakes should be operated back and forth, not in one direction. Final raking on slopes should follow the slope contour.

**E734.07 Measurement and Payment.** The estimate of area to be seeded is normally rounded up slightly to provide for the seeding of scars of operations beyond the limits of grading. The area should be checked periodically to determine whether the work is progressing as planned, and whether the amount of materials provided are sufficient.

## SECTION E735 – MULCHING

**E735.01 General.** This work consists of furnishing, placing, and anchoring mulch over seeded areas.

The purpose of mulching seeded areas is to control erosion, which could result in seed being washed away or redistributed over the seeded area. Mulch will also help conserve moisture and favor the germination and early growth of grass.

**E735.02 Spreading.** The Specifications describe the spreading requirements for small grain straw mulch. If slopes are steeper than 3:1 (horizontal to vertical) straw-coconut fiber blankets or



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bonded fiber matrix shall be used. The Inspector should ensure that the Contractor performs all spreading in accordance with the Specifications. [735.03]

**E735.03 Anchoring.** After spreading, mulch is anchored to the ground to hold it in place. If the mulch is not sufficiently anchored, it will not aid in erosion control. The method for anchoring mulch to the existing slope depends on the mulch material used. Anchoring requirements are stated in the Specifications. The Inspector should ensure that the mulch is properly and sufficiently anchored. Determination of whether or not the mulch is sufficiently anchored can be made based on the type of mulch material.

Straw mulch is to be anchored by crimping or tracking into the soil using mechanical equipment. If it is not sufficiently anchored, it can be blown or washed away. Both of these conditions can be easily observed during normal construction operations. If the straw is seen blowing or washing away, the Contractor should be notified so that maintenance can be performed. [735.03]

**E735.04 Maintenance.** The Contractor is required to perform all maintenance to keep the mulched area in a satisfactory condition until Completion of the Project. When mulch blows or washes away or is not properly applied, spots in the seeded areas are apparent. Normally, this is also an indication of seeding failure. The Inspector should bring these conditions to the Contractor's attention so that reseeding and remulching can be accomplished promptly.

## SECTION E736 – SODDING

**E736.01 General.** This work consists of preparing the ground area and furnishing and placing approved sod.

**E736.02 Placing.** The Specifications state that sod may only be placed when the soil is moist and favorable for growth. The Specifications also state that sod can not be placed between November 1 and April 1 unless the weather and soil conditions are favorable and permission is granted. [736.05]

**E736.03 Laying the Sod.** After raking and leveling, the area to be sodded must be watered by the Contractor so that it is moist before the sod is placed. The Inspector should consider the soil moist enough for sodding when the top 2" (50 mm) of soil has been watered within four hours. The Inspector should consider the soil too wet when the soil can be compressed by walking on it. [736.05] [736.06] [736.07]

The Contractor is to be made aware of the importance of following the Specifications, particularly when laying and joining sod and plugging joints. The Inspector should carefully observe these items, making sure the sod strips are packed tightly together so that no joints are evident when finished. [736.07]

**E736.04 Maintenance of Sod.** The Inspector should ensure that the Contractor keeps the sod moist until growth is established. The Inspector should check the sod regularly to ensure that it is moist. It is difficult to determine when grass shows evidence of being too dry before it is damaged beyond repair. Dry grass may be of a grayer or lighter shade of green than normal but not necessarily tinged with brown or tan. The blades of grass may also begin to droop or curl if

the grass is dry. Generally, a dry period of a week during hot months is too long a period to elapse without watering the sod. [736.07]

If the sod appears to be dry, the Inspector should remind the Contractor that it is required to maintain the sod. Any sod that is shrinking, burning, or turning brown should be replaced by the Contractor. [736.07]

## SECTION E737 – PLANTING

**E737.01 General.** This work consists of furnishing and planting specified plants, shrubs, and trees and the replacement and cultural care of the material.

**E737.02 Receiving Deliveries.** The Inspector and the Contractor should discuss the proposed schedule for planting prior to the initiation of planting operations. This discussion should include planning for the Contractor to provide advance notice as to when plants are to be delivered to allow for inspection and collection of delivery tickets. Discussing the planting schedule before planting operations begin will allow the Contractor enough time to order the plants and ensure their timely delivery. The discussion should also enable the Inspector to plan inspections on a timely basis and to ensure that planting will be performed in accordance with the Specifications. [737.02]

Prior to the delivery of plants, the Contractor should determine whether space is required for heeling-in purposes. If space is required, the trenches should be opened just prior to arrival to avoid delays in “heeling-in” the plants. The trenches should be long and deep enough to accommodate the shipment. The Contractor should open the plant bundles, lay the plants separately, backfill over the roots, and compact the soil to prevent air from reaching the roots. The Contractor should lay the same type of plant and those of a similar size in the same row, with the end plant carrying the identification tag. This plant should be the last plant placed. Balled and burlapped (B&B) deciduous trees should be placed flat so that the tips are supported and not able to blow about. Balls of earth should be covered with an approved mulch or soil, and watered properly. Plant balls are not to be saturated with water.

The Inspector should be present when plants are delivered to collect the delivery tickets and inspect the plants. The Inspector should remind the Contractor that acceptable horticultural practices should always be followed when moving plants, because successfully moving living plants involves a number of factors, some of which cannot be controlled. The Inspector should inspect all plants received on the Project site to ensure that they are in conformance with the Plans or Specifications. The Inspector should note if any plants arrive with broken or loose root balls or have dry or insufficiently developed roots. The Inspector should also note if the Contractor plants any plants before they have been inspected. If the plants delivered do not match those listed on the delivery tickets, or are not in conformance with the Plans and Specifications as noted above, the Engineer and the Contractor should be notified. [737.02]

**E737.03 Substitutions.** If the Contractor is unable to furnish the specified types or sizes of plants, the Engineer may provide permission in writing to the Contractor for acceptable substitutions. Substitutions should not be made unless permitted by the Engineer. All data regarding the substituted plants should be included in the Project files to substantiate a claim for a change order. This data should include the number and size of the substituted plants and the

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locations where they were placed, as well as documentation that the specified types or sizes of plants were not available. [737.02]

**E737.04 Planting Periods.** Weather conditions such as frozen ground and drought, either in the nursery or collecting fields, are considered unfavorable for planting. During or following a drought, the plants may not have stored sufficient moisture to survive transplanting, and watering after planting may not be sufficient. Frozen ground can damage the root ball and may not provide sufficient moisture to the plants. Bare roots are never to be exposed when the temperature is below freezing. [106.07] [737.12]

Dates for planting stated in the Specifications are based on the temperature averages for the locality. The Engineer has the right to extend or reduce the planting period based on weather and soil conditions. In the case of extensions of the planting period, the Inspector should be aware of the weather conditions and their impact on planting. Extending planting beyond the spring date may expose the plants to excessive heat, drought, or advanced growth of the stock, which may be fatal for the plants. In relatively warm locations, extending planting earlier into the fall may be equally harmful to the plants. Any unfavorable weather or soil conditions should be brought to the Engineer's attention. [737.12]

**E737.05 Location of Plants.** Plants are to be located as indicated on the Plans. Plants can be shifted to avoid utilities, subject to the Engineer's approval. Plants should not be shifted so that they obstruct sight lines on the roadway or pose a hazard to the public or adjacent property. Any plant location that appears to pose a problem should be brought to the Engineer's attention. [107.09] [737.15]

Planting plans are used as a guide for placing plants. Generally the precise location for planting is not significant, but it is necessary to interpret the intent of the plans to meet the local conditions, such as having trees in the proper relation to utility lines and providing for safe viewing.

The Contractor should "scale off" and stake the plant locations provided on the Plans. Adjustments in the plant locations may be made by the Engineer to properly meet the site conditions. With very few exceptions, the Contractor should not be required to shift plants once approval has been given. Plaster lath is normally used to mark individual plant locations and to outline beds. [105.10] [737.15]

**E737.06 Plant Pits and Beds.** Plant pits should be dug before the arrival of plants on the Project site. Plant pits should be excavated to the actual depth of rootball, relative to the surface, as shown on the Plans. If open pits constitute a hazard, they should be temporarily backfilled with the material that will be used in planting. All plant pits should be as illustrated on the planting details. A skidway may be dug into one side of the plant pit to expedite placement and to protect trees or plants with large root balls. [737.16]

Groupings of two or more plants are considered to be plant beds. The Plans and Special Provisions specify the details of construction for plant beds. It is normally required that beds located on a slope of 1:3 (vertical to horizontal) or greater have existing vegetation cut to a height of 2" (50 mm) and have all debris removed from the planting area. When plant beds are located on a slope of 1:4 (vertical to horizontal) or less, the entire area of the planting bed should be tilled to a depth of 6" (150 mm).

**E737.07 Disposal of Excavated Soil.** The Contractor is to remove all unacceptable soil excavated from the site as soon as practical. [106.09] Acceptable soil excavated from pits and beds is to be used for planting or other approved purposes. [737.13]

**E737.08 Setting Plants.** After planting, plants may settle below the grade at which they were set. Typically, a plant with a 3' (0.9-m) ball may settle approximately 1" (25 mm), and a plant with a 5' (1.5-m) ball may settle approximately 2" (50 mm). The Contractor should allow for settlements such as these with large bare root trees and all plants with balled roots. A large portion of plant losses in heavy soil is attributed to planting too deep.

The roots of bare root plants should be spread out in the same position in which they have been growing. With the exception of material delivered in peat pots, plants delivered in containers are to have the containers removed prior to planting.

**E737.09 Backfilling.** Backfilling should be done with the soil mix indicated in the Specifications. [737.13] Backfill should be placed around the roots of bare root plants to avoid air holes and allow the roots to lie in their natural position. The packing of soil under and against roots and balled material must be thorough.

Burlap and rope or twine wrapped around root balls on B&B plants should be removed completely before the planting pit is backfilled. Care should be taken during this operation not to break or crack the root ball. A broken or cracked root ball is cause for rejection of the plant. The Inspector should observe the root ball before backfilling to ensure that it has not been broken or cracked. [737.16]

Fibrous roots on the outside of the ball should be carefully placed in their natural position while compacting the backfill.

The Specifications require that a mound of soil be formed around the edge of each pit to serve as a bowl to hold water. During winter months, the Contractor may place a break in the rim of the saucer to provide drainage. [737.16]

**E737.10 Pruning.** Pruning should be accomplished immediately after planting. Pruning is done to remove all injured or dead wood. Pruning is necessary for both the appearance and the health of the plants and should be done with care by skilled workers. All pruning should be in accordance with the Specifications. If the Inspector notices plants that need further pruning or plants that were not pruned properly, the Contractor should be notified so that corrective action may be taken. [105.02] [737.16] [737.17]

**E737.11 Wrapping.** The trunks of all trees are to be wrapped in burlap from the lowest main branches to the base of the tree. Each pass of the wrapping material should overlap the previous pass by 1½" (38 mm). The wrapping is to be tied with twine at the top and bottom and at 1' (300 mm) intervals for the length of the trunk. The Inspector should ensure that all trees are wrapped in accordance with the Specifications. Tree wrapping should be removed from the tree at the time of semi-final inspection. [737.10] [737.16]

**E737.12 Staking and Guying.** Staking is a method of supporting a tree in which one or more stakes are set parallel with the trunk of the tree. Guying is a method of supporting a tree in which three or more steel wires are fastened to the tree trunk and to stakes. Anchoring is a method of supporting a tree in which three or more guy wires are fastened to anchors driven into the ground

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to place the guy wires in tension. Bracing is a method of supporting tree branches with cables, rods, or similar devices.

Requirements for staking and guying are generally shown on the Plans. Staking and guying are to be done immediately after or concurrently with the planting operation. All staking and guying is to be completed the same day as planting and mulching unless otherwise approved by the Engineer. Serious damage to the root system of unsupported trees may result from the swaying of the tops of the trees in the wind. The Inspector should ensure that the Contractor performs this work in accordance with the Specifications and records the location of any trees that are not staked and guyed on the same day that they are planted and mulched. [737.16]

When stakes are required, they are to be driven so that the plant balls are not seriously injured. Refer to the Plans for information on the position and depth for stakes.

Stakes or anchors for guy wires should be spaced at equal distances around the tree. The stakes should be driven into the ground at an angle that will allow each stake to be perpendicular to the guy wire. Ropes, wood staves, and heavy cloth padding are to be used only as a temporary measure. After the installation is complete, all guy wires should be tight without having used more than one half of the take-up of the turnbuckle or driving the stakes flush with the ground. [737.10]

**E737.13 Maintenance.** Proper watering is the most important maintenance item. Periods without sufficient rain, usually one week, require watering unless the plants are dormant. The Contractor is responsible for watering as necessary to keep all plants healthy. The Contractor should be aware that excess water can damage plants. Roots that are kept too wet will show a blue color and have an odor of decay. [737.17]

Weeding is important because weeds affect the moisture and nutrient supplies available to the plants. Herbicides, applied properly to prevent weed growth or to kill existing weeds, are an acceptable means of controlling weeds. The person applying the herbicides must be certified by the Delaware Department of Agriculture as a Commercial Pesticide Applicator and must carry a card issued by that Department evidencing such certification. In the absence of any herbicide use, hand weeding is more effective than cultivating. Weeding should be accomplished by cutting the weeds at ground level or pulling them. If the Contractor has not acted to properly maintain the plant material, the Contractor should be notified in writing of the necessity to perform any required maintenance including watering, weeding and insecticide application. If verbal notification is given, the instructions must also be given officially in writing.

The Contractor is responsible for watering, weeding, pruning, applying insecticides or fungicides, repairing and replacing stakes and guy wires, and repairing plant bowls as required. The Engineer will specify when maintenance work should be done. The Inspector should ensure that the Contractor performs all maintenance work in accordance with the Specifications. [737.17]

**E737.14 Replacement.** The Inspector must be aware of the interpretation of the phrases “in an unhealthy or badly impaired condition” or “a satisfactory living condition” as they refer to each size and kind of plant on the Project. Plants must be in a healthy growing condition. If there is evidence of an excess quantity of dead twigs, few and small buds, a scarcity of leaves, small leaves, or leaves that do not have a healthy color, plants may require replacement. Dead and rejected plants are to be promptly removed from the Project site. The Inspector should bring any

conditions that indicate that plants are in an unhealthy or badly impaired condition to the Engineer's attention.

**E737.15 Records.** A separate page in the records book should be used to list each separate kind of plant shown on the Contract. Individual records should reflect the unit price, size, and quality of plants shown on the Contract. Entries should also indicate the work as accomplished, including the date, reason for all plant rejections, and the plants returned to the "heeling-in" grounds. The shipping list furnished by the Contractor or the list accompanying deliveries from the "heeling-in" grounds may be used as a temporary record. The lists indicating the type, number of units planted, and the date should be transferred to the records book at the end of the day. Each item should be summarized for monthly and final estimates. If one or more units become unsatisfactory, the items should be recorded in red as a debit, with an explanation. Subsequent work, such as pruning, mulching, staking, guying, and additional planting, requires approval. Final acceptance is not made until the entire work of planting meets the requirements of the Specifications.

## **SECTION E744 – CONDUIT JUNCTION WELLS**

**E744.01 General.** This work consists of constructing conduit junction wells.

The Inspector should be familiar with the Plans, Specifications, and Standard Construction Details prior to the start of electrical work. The electrical layout should be discussed with the Contractor at the Project site prior to the start of work to determine whether any omissions or changes may be required. The quantities of materials shown on the Plans should be inventoried to avoid omissions, irregularities or delays.

**E744.02 Materials.** The Contractor is responsible to provide the District Engineer with nine copies of the appropriate electrical shop drawings for approval prior to the start of work. **[105.04]** The Contractor is not to install any materials prior to approval. The drawings are to include the types and manufacturers of the materials to be used on the Project.

The Inspector should make field inspections of the condition of the materials at the time of arrival for compliance with the Plans, Specifications, and shop drawings. Any questions regarding the acceptability of a material should be referred to the District Engineer for clarification with the Materials and Research Section. Substitution of a similar electrical item for the specified or previously approved item is not allowed unless specifically authorized in writing by the Engineer.

**E744.03 Junction Well Installation.** Junction wells are not to be installed in depressions, because they will act as catch basins collecting surface drainage. Junction wells are to be installed flush or slightly higher than the surrounding surfaces in accordance with the Standard Construction Details. **[744.03]**

## **SECTION E745 – CONDUITS (NON-METALLIC OR GALVANIZED)**

**E745.01 General.** This work consists of installing conduits (non-metallic or galvanized) with all necessary fittings.

The Inspector should be familiar with the Plans and Specifications prior to the start of electrical work. The electrical layout should be discussed with the Contractor at the job site prior

to the start of work to determine whether any omissions or changes may be required. The quantities of materials shown on the Plans should be inventoried to avoid omissions, irregularities or delays.

**E745.02 Materials.** The Contractor is not to install any materials prior to approval. The Inspector is required to verify that all the required certificates of compliance are in the Project records.

The Inspector should make field inspections of the condition of the materials at the time of arrival on the Project site for compliance with the Plans and Specifications. Any questions regarding the acceptability of material should be referred to the District Engineer for clarification or discussion with the Traffic Section. Substitution of a similar electrical item for the specified or previously approved item is not allowed unless specifically authorized in writing by the Engineer.

**E745.03 Conduit Installation.** The location of the conduit runs shown on the Plans is for the purpose of circuitry and bidding only. During actual construction, it may be advantageous to alter or change the runs to avoid obstacles unforeseen during the design stage or for other valid reasons. When using steel conduit, care should be taken when making field bends. Only approved tools, such as a hydraulic bender, are to be used. Smooth bends are required. Kinks or flat places in the bend are to be rejected. Steel conduit ends must be cut square, and all field cuts are to be made with a pipe cutter. Normally when steel conduit is screwed together, all threads are covered by the couplings and the ends of the conduit are butted tightly together. The Inspector should use a wrench when testing couplings to ensure that the joints are tight. Field cuts in non-metallic conduit are also to be square. Couplings are to be inspected to ensure that the proper gaskets are installed correctly and that the joints are tight. [745.03]

## SECTION E746 – POLE BASES

**E746.01 General.** This work consists of furnishing pole bases for poles at locations as directed by the Engineer.

The Inspector should be familiar with the Plans, Specifications, and Standard Construction Details prior to the start of electrical work. The Inspector should specifically review Standard Construction Details T-5 and T-6, as these are the sheets the Contractor will refer to during construction. The electrical layout should be discussed with the Contractor at the job site prior to the start of work to determine whether any omissions or changes may be required. The quantities of materials shown on the Plans should be inventoried to avoid omissions, irregularities or delays.

**E746.02 Materials.** The Contractor is not to install any materials prior to approval. The Inspector is required to verify that all the required certificates of compliance are in the Project records. The Inspector should note that for certain types of pole bases, the Department will furnish the anchor bolts. In these cases, the Inspector should ensure that these anchor bolts are available when the Contractor needs them. [746.02]

The Inspector should make field inspections of the condition of the materials at the time of arrival for compliance with the Plans and Specifications. Any questions regarding the acceptability of a material should be referred to the District Engineer for clarification or

discussion with the Traffic Section. Substitution of a similar electrical item for the specified or previously approved item is not allowed unless specifically authorized in writing by the Engineer.

**E746.03 Pole Base Installation.** The pole bases are to be located behind guardrails, sidewalks, or outside the shoulders. In the event that shoulders or sidewalks are constructed wider than the lighting was originally designed for, the foundation location is to be adjusted so that the pole bases are behind these features. If the lateral clearance of a foundation is changed, the Inspector should ensure that the bracket arm length is of the proper size so that the correct overhang over the pavement is maintained. The correct pavement overhang is usually shown on the lighting Standard Construction Details. [746.03]

## SECTION E749 – REINFORCED CONCRETE SIGN FOUNDATIONS

**E749.01 General.** This work consists of constructing reinforced portland cement concrete foundations for sign structures.

Prior to starting concrete sign base construction, the Inspector should be familiar with the Plans and Specifications. The layout should be checked in the field as soon as possible to determine if there are any interferences that may necessitate relocating the sign foundation. Because the Bureau of Traffic will be furnishing the embedded stub post (see Standard Construction Detail T-7), the Inspector should coordinate timely delivery to the Contractor to avoid delaying the work.

**E749.02 Sign Base Construction.** The location of signs as shown on the Plans is for the purpose of bidding and general sign location only. During construction, it may be advantageous to alter the location slightly or place the sign behind a guardrail or ahead of a light standard. Major location changes are not authorized without approval from the Engineer. For sign foundations where anchor bolts are used instead of a Department-furnished stub post, the Inspector should check anchor bolt sizes and spacings to ensure a proper fit with the sign post base. The bases are to be inspected for correct spacing and alignment on multi-post installations. [749.03]

## SECTION E799 – OTHER MISCELLANEOUS CONSTRUCTION

**E799.01 Permanent Traffic Signs and Signals.**

- (a) *Inspection.* Prior to starting concrete sign base construction, the Inspector should be familiar with the Plans and Specifications. The layout should be checked in the field as soon as possible to determine any mistakes by the Contractor that need to be corrected or omissions by the Department. The quantities of materials listed on the Plans should be reviewed to avoid omissions or irregularities.
- (b) *Materials.* The Inspector is required to ensure that the Contractor furnishes the appropriate shop drawings, showing sign face layouts and fabrication techniques which are to be approved in the same manner as the rest of the working drawings. [105.04] The shop drawings required to be submitted for review and approval are prescribed in the Special Provisions. The Inspector is responsible to verify that all required certificates of compliance are on file in the project records. [105.02] [106.03] The Inspector should make a field inspection of the condition of the



materials at the time of arrival and for compliance with the Plans, Specifications, and shop drawings. Any questions concerning the acceptability of a material or finished sign is to be referred to the District Engineer.

Substitution of an item with a similar item is not to be allowed unless specifically authorized in writing by the Engineer.

- (c) *Sign Posts.* Non-metallic slings are to be used when erecting signposts. Non-metallic slings will reduce the chance of damage to galvanized, painted or finished aluminum surfaces.
- (d) *Sign Face Assemblies.* The Inspector should check the legends on the face of each sign upon arrival at the Project site to ensure that they are correct. The inspection should include checking the letter size and spacing for conformance with the shop drawings. Signs should be handled and stored carefully. Ladders or other types of equipment placed against an unprotected sign face will scratch the surface. Should any foreign substance such as mud or dirt be found on the face of the sign, a clean soft cloth is to be used for cleaning. If rubbing is necessary, it should not be extensive, and pressure should not be used. If light rubbing will not remove the foreign substance, clean water should be applied, and then the sign should be rubbed lightly. The cloth used should be turned often to ensure a clean cloth surface against the sign face.

The Contractor is to be very careful while removing any foreign material from the sign face. Heavy rubbing will scratch the surface and cause premature weathering to the damaged area.

- (e) *Erection Hardware.* Hardware is to be checked both for conformance with the Specifications and for the proper quantities upon arrival on the Project. A shortage of clamps or bolts at the time of erection may cause a delay.
- (f) *Lighting or Signal Standards.* When erecting lighting or signal standards, non-metallic slings should be used to reduce the danger of damage to galvanized, painted, or finished aluminum surfaces.
- (g) *Traffic Signal Systems.* Traffic signal systems are a very special type of work. All work is to be accomplished in strict accordance with the Plans and Specifications.
- (h) *Project Completion.* All traffic control devices and illumination structures are to be in place and operating properly prior to the Project being officially opened to traffic. The District Engineer and the Traffic Section are to be notified upon completion of a traffic signal project and before traffic is allowed on the Project. Some slight adjustments may be required, as the preliminary timing of signal lights is based on past traffic counts at the intersection. The timing and sequence of the signal lights are to be checked for proper operation prior to opening the Project to traffic.

#### **E799.02 Utility Adjustment Construction.**

- (a) *General.* This Subsection provides information related to inspection of utility adjustment work. Administrative procedures are discussed in Section B13.00.
- (b) *Definitions.* The following definitions apply specifically to utility work, and may be different
  - (1) *Agreement.* Also referred to as a letter agreement, this is a legal instrument between a utility and the Department that covers the utility work that the Department has determined to be reimbursable. The Agreement states the terms and conditions by which the work and subsequent payment will be handled. An executed Agreement is required prior to the performance of any work that is to be reimbursed.
  - (2) *Authorization.* This term refers to the State authorizing a Utility to proceed with any phase of a project.
  - (3) *Betterment.* This term refers to any facility upgrade that is not attributable to the highway construction and is made solely for the benefit of and at the election of the Utility. Betterment includes increasing the functional capacity of or service improvements in the facility being relocated or adjusted.
  - (4) *Construction.* This term refers to the actual construction work and all related activities, including Utility relocation or adjustments.
  - (5) *Cost of Relocation.* The entire amount paid by or on behalf of the Utility properly attributable to the relocation, after deducting from that amount any increase in value of the new facility and any salvage derived from the old facility.
  - (6) *Cost of Right of Way.* This term refers to the cost of land required for the relocation of the Utility facility.
  - (7) *District.* Refers to the respective area of responsibility as designated within the Division of Highway Operations.
  - (8) *District Engineer.* The Engineer officially assigned managerial responsibility for a District.
  - (9) *Division.* This term refers to the Division of Transportation Solutions of the Delaware Department of Transportation.
  - (10) *Indirect or Overhead Costs.* This term refers to costs that are not readily identifiable with one specific task, job, or work order. Such costs may include indirect labor, social security, taxes, insurance, storage expense, and general office expenses. Costs of this nature generally are distributed or allocated to the applicable job or work orders, other accounts, and other functions to which they relate. Distribution and allocation is made on a uniform basis that is reasonable, equitable, and in accordance with generally accepted cost accounting practices.
  - (11) *Inspector.* The individual the Department assigned the responsibility for inspecting the work of a project.
  - (12) *Preliminary Engineering.* This term refers to locating existing utilities, making surveys, and preparing plans and estimates for the relocation prior to the execution of agreement.

- (13) *Reimburse*. This term refers to the use of Federal or State funds that may be allowed to compensate the Utility for relocation costs to the extent provided by law.
- (14) *Salvage Value*. This term refers to the amount received from the sale of Utility property that has been removed, or the amount at which the recovered material is charged to the Utility's accounts if retained for future use.
- (15) *State*. This term refers to the State of Delaware.
- (16) *Utility*. This term includes every individual, partnership, association, corporation, joint stock company, agency or department of the State, or any association of individuals engaged in the protection in common of a productive enterprise (commonly called a "cooperative"), their lessees, trustees, or receivers appointed by any court whatsoever, who now operate or hereafter may operate, within this State, any railroad, street railway, traction railway, motor bus, electric trackless trolley coach, taxicab, express, steam, manufactured gas, natural gas, electric light, heat, power, water, telephone or telegraph, heating oil for residential consumption delivered directly to residences by means of a pipeline service, system plant, or equipment for public use.
- (17) *Work Order System*. This term refers to a procedure for accumulating and recording into separate accounts of a Utility all costs to the Utility concerning any change in its system or plant.
- (c) *Pre-construction Meeting*. Following the award and execution of a highway improvement contract, representatives of the Utility companies and other interested parties should attend the pre-construction meeting as described in Section B2.00.
- (d) *Notice to Proceed*. The notice to proceed with the work of the highway improvement contract is given by the appropriate District Engineer. Should authorization for work under a Utility agreement be given and work begins prior to the start of operations under the highway improvement contract, the District Engineer will assign an Inspector for the work under the Utility agreement. The Inspector will maintain a record of the progress of the Utility adjustments made before work on the highway improvement contract begins.
- (e) *Inspection of Work*. The Inspector should monitor Utility adjustments to determine that the facilities are not in conflict with the planned highway improvement. The Contractor and the Utility are to use the same reference datum when setting grade stakes, and confer with the District Engineer before establishing any underground, overhead, or lateral installations.
- (f) *General Duties of the Inspector*. The Inspector is responsible for determining that all trench backfilling is performed in accordance with the Specifications, having a listing in the Project log of all major items of material used, and signing material slips along with the Utility supervisor. Material for backfill is supplied by the Contractor and paid for by the Department. The Inspector is required to list in the Project log the type and number of pieces of equipment, the number of Utility personnel working on the Project, and each time an inspection is made by a representative of the Utility or the State. If the Utility work is done by the

Department's Contractor, the Inspector is required to bring to the attention of the Utility's engineer/inspector any infractions of the Specifications that may occur. Any infractions by the Utility's own forces are to be brought to the attention of the Utility official in charge of the work. If corrective action is not taken, the matter should be brought to the attention of the Department Utility Coordinator in charge of the work. **[105.02]**

(g) *Contract Records.*

- (1) *General.* The Inspector will maintain daily construction records so it can be determined whether the proposed work is being accomplished in accordance with the requirements of the agreement between the Department and the Utility, as described below, and to furnish evidence necessary for recommending payment to the Utility.
- (2) *Force Account Agreements.* The Inspector is required to keep a daily record of the numbers of workers and job classifications employed, the materials used, major items of equipment used, and any other information that may be of assistance in verification of billing charges. A permanent record is to be kept of all materials removed from the Project site that are returned or scrapped and the dates of removal. At the completion of the Utility work, this record is to be signed by the Inspector.

If the Utility has the work performed by an existing continuing contractor on a unit price basis, daily records of workers and equipment are not required. However, daily records of the work operations by station and the number of units of work completed are required. Work accomplished by an existing continuing contractor on a force account basis requires daily records of workers and equipment in the same manner required for work performed by the Utility on a force account basis.

- (3) *Unit Price Basis (General Roadway Contract).* When the Utility relocation is performed by the Contractor or its agents, a daily record is to be made of the work operations by station and the number of units of work completed. This information is to be entered in the Project Diary for each day work is performed.
- (4) *Lump Sum Agreements.* When a Utility relocation is performed by a Utility under a lump sum agreement, daily records are not required of hours worked, material items, or equipment time. The Inspector is required to maintain sufficient records of the work performed to be able to provide certification that the work has been accomplished satisfactorily and in the manner prescribed in the agreement.
- (5) *Minor Changes in Approved Work.* The District Engineer may authorize the Utility to do all work involving minor changes in the quantities or items not included in the approved estimate that may be necessary to accomplish the intent of the approved Utility agreement, as long as the approved force account estimate is not exceeded. This action may be taken without formal approval, with the understanding that the Project records and final billing provide adequate documentation of such minor changes.

Substantial changes in the scope of work covered by the Utility agreement or substantial changes in location that will result in work of a

different nature or work that exceeds the approved force account estimate must be submitted for approval by the State and FHWA, both orally and in writing, and will, if necessary, be reviewed in the field. If such proposed changes are found satisfactory, oral authorization for such changes may be given and confirmed by letter. Prior to final billing, revised plans will be required so that the State's files reflect the true location of the relocated utility's facilities.

Minor or substantial changes in work may necessitate revision of betterment or extended service life percentages established at the preliminary stage and agreed upon as being applicable to the final billing.

- (6) *Inspection of Recovered Materials.* The purpose of inspecting recovered materials is to prevent the junking or scrapping of all recoverable materials and to ensure that proper allowance is made for any salvaged items. FHWA is to be notified by the Department through dated, written correspondence of the time and location where the recovered materials are to be available for inspection and where they are to be sold or scrapped. The written correspondence is to provide a listing of the materials to be sold or scrapped. This requirement is necessary to preclude the Utility from being cited for the salvage value of the materials during an audit of the work. A statement is required on the final bill that credit has been allowed for all material and that the items were available for inspection and proper notice given.
- (h) *Responsibility of District Offices.* District Utility office responsibilities include:
  - (1) Inspection of Utility construction to ensure that the Utility work is coordinated with other construction activities. The Utility work should be in conformance with the Specifications, FHWA's Federal-Aid Policy Guide Part 645, and the approved Utility plan.
  - (2) Maintaining accounting and documentation of all Utility labor, materials used, and materials scrapped.
  - (3) Maintaining a separate field record file and Utility diary for each specified Utility project authorized.
  - (4) Approving and signing work orders or other satisfactory forms covering and indicating all Utility labor and materials used on the Project each day. All copies of this daily form are to be signed by representatives of both the Utility and the District, with at least one copy retained by the District and one copy for the Utility's use in accumulating field costs for billing to the Department.
  - (5) Inspecting and recording all materials scrapped by the Utility with a representative of the Utilities Section of the Department. Prior notification to the Utilities Section is necessary to coordinate this activity. All materials are to be inspected jointly prior to disposal.
  - (6) Reviewing, verifying, and approving all the Utility invoices from data recorded in the field control records concerning Utility work accomplished in the field. (The invoices are furnished by and are to be returned to the Utilities Section after processing.)

- (7) Notifying the Utilities Section of any required revision to the approved Utility plan, specification, and cost estimate; providing coordination, information, and documentation of revisions.
- (8) Forwarding the records and data supporting all the Utility work accomplished on a specific project to the Utilities Section after completion of all the work. The data is compiled and reviewed for final invoice and determination of Federal Aid participation.
- (9) Scheduling periodic Utility coordination meetings with interested parties as the work progresses, and providing notification to the Utility of conflicts.

## DIVISION E800 – MATERIAL DETAILS

### SECTION E800 – GENERAL

**E800.01 General.** In general, material inspections required in Division 800 of the Specifications will be performed by personnel from the Materials and Research Section. The Inspector on the Project, however, should be familiar with the requirements of Section 106 and Division 800 of the Specifications.

### SECTION E812 – PORTLAND CEMENT CONCRETE

**E812.01 General.** Concrete is composed of sand, gravel, crushed rock, or other aggregates held together by a hardened paste of cement and water. The thoroughly mixed ingredients, when properly proportioned, make a plastic mass that can be cast or molded into a predetermined size and shape. Upon hydration of the cement, concrete becomes stone-like in strength and hardness and is useful for many purposes.

**E812.02 Background.** Concrete is used in nearly all types of construction, from highways, canal linings, bridges, and dams to artistic buildings. With the addition of reinforcement to supply needed tensile strength, concrete has become the leading structural material. The popularity of concrete in the United States is attested to by its continuous growth in production. At the turn of the century, cement production was approximately 10 million barrels of cement annually, compared to present production figures of more than 240 million barrels annually. (A barrel of cement is equivalent to approximately 375 lbs (170 kg of cement).)

Concrete technology has progressed and evolved with the times and with new discoveries. In the latter part of the 19<sup>th</sup> century, concrete was ordinarily placed nearly dry, and compacted with heavy tampers. There was practically no reinforcement used at that time. Reinforcing steel for use in concrete was developed in the early part of the 20<sup>th</sup> century. Very wet concrete mixes became popular as the concrete had to be able to flow around the reinforcing steel as it was poured into the forms. These wet concrete mixes did not have good strength or durability. The use of wet concrete mixes continued until investigations began to emphasize the importance of using scientifically designed mix proportions to produce uniform concrete of improved workability, durability, and strength. Notable among the early investigations were those of Abrams, who formulated the “water-cement ratio law” and demonstrated the importance of restricting this ratio to the lowest value consistent with the desired workability of concrete for the particular job. The development of vibration to consolidate concrete aided materially in the placement of lower slump mixes and eliminated the necessity for “sloppy” mixes.

**E812.03 Design Uses.** Reinforced concrete has become one of the most widely used materials of engineering construction because of the ease with which concrete and steel can be fabricated into structural members, utilizing the desirable attributes of both materials. Concrete is weak in tension; steel is vulnerable to corrosion and to temperatures in excess of 800 degrees Fahrenheit (427 degrees Celsius). If steel bars are embedded properly in the cross sections of concrete members, the steel can be made to carry the tension while the concrete resists the compression and protects the steel against corrosion and fire damage. Because of the adhesion between concrete and steel, and because of the mechanical interlock between deformations on the steel bars and the surrounding concrete, the concrete supplies the grip required to enable the steel to

resist tensile forces. Steel is also used to reinforce concrete compressively in columns and near the compression face of some beams; to resist the diagonal tension that accompanies shear in beams; to serve as ties and spiral reinforcement in columns; and to minimize or distribute cracks that tend to form because of temperature changes or shrinkage in concrete.

**E812.04 Requirements for Concrete.** Since concrete is a mixture in which a paste made of portland cement and water bonds together fine and coarse particles of material, it is readily seen that by varying the proportions of the ingredients, innumerable combinations are possible. These various combinations result in concrete of different qualities. When the cement has hydrated (combined chemically with water), the plastic mass changes to a material resembling stone. This period of hardening is called curing. Curing requires three things: time, favorable temperatures, and the continued presence of water.

To fulfill design requirements, it is essential that the hardened concrete have, above all else, strength and durability. In order that the concrete in its plastic form can be readily placed in the forms, another essential quality is workability. When determining the various proportions of the mixture, it is important that the designer understand the purpose for which the concrete is to be used and the exposure to which the concrete will be subjected. For example, when watertightness is required, concrete must be dense and uniform in quality. After the purpose and exposure of the material has been resolved, the following factors determine the quality of the concrete: suitable materials, correct proportions, proper methods of mixing and placing, and adequate protection during curing.

**E812.05 Admixtures.** Substances added to concrete to improve workability, accelerate the setting time, harden the surface, increase the waterproof qualities, or otherwise alter concrete's characteristics are known as admixtures. Many of these substances are proprietary compounds and contain hydrated lime, calcium chloride, and kaolin. Calcium chloride and calcium oxychloride are the admixtures generally used as accelerators.

Only admixtures that have been approved by the Materials and Research Section are permitted for use.

**E812.06 Value of Air-Entrained Concrete.** Air-entrained concrete can be produced by using air-entraining portland cement or one of the various types of portland cements to which a suitable air-entraining admixture has been added during the manufacturing process at the plant. This process should be done only where engineering supervision and facilities are available for accurate control.

Only air-entrained concrete with additives that have been approved by the Department and introduced at the batch plant is permitted for use.

The advantages of air-entrained concrete are considered to be:

- (a) Prevention of the disintegrating effects of chlorides and freeze/thaw effects.
- (b) High durability unaffected by the action of salt spread on pavements to melt ice.
- (c) Elimination of surface scaling.
- (d) Increased resistance to aggressive action of sulfates and seawater.



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- (e) Increased workability and cohesiveness.
- (f) Reduced segregation and bleeding tendency.
- (g) Production of a more homogeneous and durable concrete and better appearance.

**E812.07 Concrete Release.** Portland cement concrete for any item of use must not be released by the Inspector or, in the case of truck/central mix concrete, loaded until the Inspector at the batch plant has approved the mixing operation. This control is necessary to preclude trucks of concrete from sitting longer than the allowed time limits. When pouring cast-in-place piling or similar pours where the pouring rate is relatively slow, the amount of concrete hauled by the trucks is to be reduced so that the concrete can be placed within the allowed time limit.

**E812.08 Concrete Inspection Procedures.** Procedures for the inspection of concrete may be found in the following Sections or Subsections of this Manual: D1.06; D2.00; E602; E603; E604 and E701.

**E812.09 Central Mix Inspection.** Procedures for the inspection of central mix plants and plant batching may be found in the procedures of the Materials and Research Section.

## **SECTION E823 – HOT-MIX, HOT-LAID BITUMINOUS CONCRETE**

**E823.01 General.** Hot-mix, hot-laid bituminous concrete is a thoroughly controlled hot-mixture of asphalt cement and well-graded, high quality aggregate that must be spread and compacted while in a heated condition.

**E823.02 Hot-Mix Inspection.** Hot-mix, hot-laid bituminous concrete is manufactured in commercial plants or, in some instances, in a special Project mixing plant. The mixing of the produced material is controlled by the Materials and Research Section personnel. Procedures may be found in the Department's Materials Manual.

**E823.03 Hot-Mix Placement.** Procedures for the placement of hot-mix, hot-laid bituminous concrete may be found in the following Sections or Subsections of this Manual: D1.06; D2.00; and E401.

## NOTES

This image shows a full page of blank, lined paper. It features approximately 28 horizontal blue or grey lines spaced evenly apart, typical of notebook paper. The lines extend across the entire width of the page, leaving small margins at the top and bottom. There are no vertical lines, text, or other markings on the page.

## This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

## This image shows a full page of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page, providing a template for writing. There are no margins, text, or other markings on the page.

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